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DORMANT SEEDS OF CLOVERS AND OTHER LEGUMES IN AGRICULTURAL SOILS

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(*Received for publication, 28 January 1952*)

Summary

Legume seeds were quantitatively extracted from soil samples by a new method which is described.

The viability of the seed was determined by germination tests and the strain of white clover was identified by the picrate paper method.

The density of the population of dormant seeds of legume species in the surface soil of 105 different fields throughout New Zealand was estimated.

The maximum density of any useful species was that for white clover with approximately 5,000 seeds per square foot.

The factors influencing the density of seed population and the practical significance of the observations are discussed.

INTRODUCTION

THE present study was part of a programme of work aimed at promoting an increase of leguminous forage plants in hill pastures. The programme includes the over sowing and fertilizing of pastures, the study of the germination and seedling growth of clovers, and the dissemination of clovers by grazing animals. It was considered important to know to what extent the survival of legumes in permanent pasture depends upon regeneration from seed and what opportunities occur for such regeneration. One factor determining how frequently new plants can appear is the quantity of dormant seed in the soil. It was decided therefore to examine samples of agricultural soils to ascertain the population of dormant seeds of leguminous species and to determine in what way the population was related to the soil type and climate, to the age and composition of the pasture and to the intensity of the grazing.

It has long been known that the seeds of most leguminous plants tend to be dormant because the seed coat is impermeable to water. Harrington (1916) found that samples of clover seed which had been collected by hand and therefore not subjected to the pressure and abrasion encountered in mechanical harvesting, contained high percentages of impermeable seeds; for example, 98 per cent of the seeds of white clover were in this condition when harvested. The impermeable condition of the seed coat ultimately breaks down, permitting the seed to imbibe water and germinate. The rates at which dormant seeds of pasture legumes germinate under field conditions has been determined by Harrington (1916), Leggatt (1931), and Stoa (1933). Their results are variable, but generally seedlings continued to appear with decreasing frequency over an indefinite number of years. Goss (1924) found that seeds of red clover and white clover which remained impermeable after being buried for 20 years germinated readily when scarified.

Previous workers have found that the dormant seeds of pasture legumes may form populations of considerable density. Milton (1943) estimated that one field of old pasture contained legume seed at the rate of 10 million to the acre. Champness and Morris (1948) found that in another such field white clover alone contributed 8 million seeds per acre. Brenchley and Warrington (1933, 1936, 1945) have measured the effect of fallowing and other agricultural practices upon the seed population of the soil. They estimated that a bare fallow lasting one year reduced by half the population of *Medicago lupulina* seed.

Several workers have recorded the frequency of occurrence of seeds at different depths in the soil. Brenchley (1918) found clover seeds down to 12 in. in land which had previously been ploughed. Chippendale and Milton (1934) and Champness and Morris (1948) observed that under permanent pasture seeds were almost completely confined to the top 2 in. of soil.

Methods of soil sampling for determining the buried seed population have been described by Brenchley (1918), Chippendale and Milton (1934) and Milton (1936). Champness (1949) has shown how a prescribed level of accuracy can be attained in estimating the seed populations. Most workers have determined the seed content of soil samples by spreading the soil in greenhouse boxes, counting and identifying the seedlings that appeared within a limited time. Brenchley and Warrington (1930) reduced the quantity of soil to be examined by removing with sieves those fractions which were too coarse or too fine to include seeds. Ewart (1908) separated Acacia seeds from Australian forest soils, scarified them and determined their viability.

EXPERIMENTAL METHODS

Soil samples were taken with a cylindrical sampler which lifted a core 2 in. long and approximately $\frac{5}{8}$ in. diameter. Five hundred cores were estimated to represent a square foot. Normally one sample comprising 100 cores was taken, the cores being drawn from positions selected at random. From a few fields, samples comprising 50 cores were taken, and three fields were each sampled in this way five times to estimate the sampling error. Four areas

which had been treated differently with regard to oversowing, fertilizing and grazing were sampled in two successive years to determine changes in seed content.

Soil samples were collected in all the larger agricultural districts in New Zealand. Fields were selected so as to include a diversity of soil, climate and cultural treatment. The hill pastures sampled were all in areas sown about 60 years previously following the destruction of forest by fire. The lowland pastures varied in age from 1 to 40 years, but all the areas had been in pasture throughout most of their agricultural history.

Samples were collected during the period August to November, 6 to 9 months after the seed formed in the previous season had ripened. By that time all readily viable seed would have germinated, leaving only the more persistently dormant seeds.

The following steps were taken to extract the seeds contained in soil samples: (1) The sample was washed over two wire sieves having apertures of 0.16 in. and 0.01 in. respectively. (2) The trash held in the first sieve was dried and rubbed between sheets of corrugated rubber to release any seeds held in husks or burrs. (3) The second sieve was sufficiently fine to retain any legume seeds and therefore the material passing through, including all clay and silt, was discarded. (4) Material retained by the second sieve, consisting of sand together with seeds and other particles of vegetable matter, was dried and stirred into a beaker of carbon tetrachloride. The lighter material, including all seeds, floated, and was thus separated from the sand. (5) When dry, the light material was winnowed and sieved and the seeds of leguminous species were sorted and counted, identification being on the basis of external seed characters.

The viability of all seeds was determined by germination tests. The seeds were first scarified by rubbing them between sheets of glass paper and then placed on moist filter paper in Petri dishes and incubated at 15°c. The germination counts were made after 14 days.

White clover seed from eight areas was tested by the picrate paper method employed by Foy and Hyde (1937), to distinguish between clover of good and poor agronomic types.

RESULTS

The variability of samples was determined by taking five separate samples from each of three different fields. The results are shown in Table I.

TABLE I. VARIATION IN NUMBERS OF WHITE CLOVER SEEDS IN REPLICATE SAMPLES FROM 3 FIELDS

(Each sample comprised 50 cores and represented 0.1 sq. ft.)

Sample No.	Number of White Clover Seeds per Sample		
	Field 1	Field 2	Field 3
1	18	9	18
2	34	25	19
3	26	25	36
4	18	18	18
5	25	25	34

It was calculated that for areas of similar variability and similar seed content, i.e., 230 per sq. ft., the repeatability of such counts and detection power of comparisons based on them are as shown in Table II.

TABLE II. CONFIDENCE LIMITS OF ESTIMATES OF SEED POPULATION DENSITY FOR FIELDS HAVING THE VARIABILITY AND MEAN SEED CONTENT (230 PER SQ. FT.) OF THOSE IN TABLE I

No. of plugs per field	50					100				
No of fields in a group	1	2	4	8	16	1	2	4	8	16
95% Confidence limits for mean count per sq. ft. for groups	430–90	360–120	320–150	290–170	270–190	360–120	320–150	290–170	270–190	260–200
Difference between group means required for significance at 5% level	240	170	120	85	60	170	120	85	60	42

The criteria of the above table are valid only for the type of pasture specified. They should be used with caution in cases where there are radical changes of seed content or variability from those investigated.

The frequency of occurrence of seeds of leguminous species in 105 different fields is shown in Table III. The areas have been grouped partly according to the intensity of grazing and partly according to soil type and topography. There is also shown for eight areas the comparative concentration of cyanoglucoside in white clover seedlings raised from dormant seeds extracted from the soil.

Table IV shows the average results of germination tests on seeds of legume species recovered from soil samples. In all cases the seed was scarified before testing.

TABLE III. DENSITY OF POPULATION OF LEGUME SEEDS IN THE TOP 2-in. OF SOIL OF 105 DIFFERENT FIELDS EXPRESSED AS THE NUMBER OF SEEDS PER SQUARE FOOT.

Field No.	Characteristics of the areas	Number of seeds per square foot							
		White Clover	Red Clover	Strawberry Clover	Lotus major	Lotus hispidus	Subterranean Clover	Suckling Clover	Other annual legume species
1	Pasture land where white clover seed had been harvested within the previous 5 years; Manawatu, Hawkes Bay and Wairarapa districts.	465(a)						10	
2		1730(a)							
3		1800(a)						145	
4		260(a)						570	
5		1340(a)						3570	
6		710	10				670	350	
7		880	30					180	10
8		1110						20	
9	Pasture land where red clover seed had been harvested within the previous 5 years; Wairarapa, Hawkes Bay and Canterbury districts.	15	95					30	
10			1190				10	65	35
11		70	670					295	10
12			130					610	20
13		450	70					1570	
14		20	1310				10	10	15
15		10	25				10	30	
16		160	250					15	10
17		130	155					5	10
18		15	400						
19		30	125				5	5	5
20		10	50					10	
21	Pasture land where subterranean clover seed had been harvested within the previous 5 years; Manawatu and Hawkes Bay districts.	15					25	25	
22		10					300	35	260
23	Cattle pastures on fertile plains; Manawatu, Hawke's Bay, Taranaki Waikato, Bay of Plenty and Taieri districts.	305							
24		300							
25		105							
26		115							
27		50						16	
28		325						27	
29		330					80	10	
30		120						65	
31		95						30	
32		280	10				60		10
33		110			5		5	25	
34		145						10	
35		300			10				
36		40						130	
37	Sheep pastures on fertile plains; Taranaki, Manawatu and Southland districts.	105						5	
38		20						20	
39						5		15	
40		130						180	
41								10	
42	Lowland pastures on light soil subject to intense summer drought; Hawkes Bay and Wairarapa and Western Manawatu districts.	50						3330	
43		20					270	110	700
44		20					960	140	760
45							300	3310	60
46							70	85	110
47		10					680	350	650
48		35				15	470	175	590
49		10					670	350	630
50		10						2075	1620
51							70	80	110

TABLE III. (Contd.)

Field No.	Characteristics of the areaS	Number of seeds per square foot							
		White Clover	Red Clover	Strawberry Clover	Lotus major	Lotus hispidus	Subterranean Clover	Suckling Clover	Other annual Legume species
52	Pastures on coastal sand subject to winter flooding; Manawatu district.	75		145			670	780	170
53		40		20			390	1895	15
54		205		25			30	245	15
55		115		70					5
56	Pastures on gumland clay; Auckland and Manakau Peninsula districts.	15			115	380		55	
57		100			50	920		130	15
58		115			25	415		630	
59		820			150	1180		730	
60		30	20		5	15			
61						660		40	
62	Pastures on pumice land; Waiouru, Rotorua and Bay of Plenty districts.	732						25	
63		5020	10					80	
64		550	5					3240	
65		20	10					130	
66		15				20		880	
67		140						40	
68		55			15			155	
69	Hill pastures in regions with high summer rainfall; Whangamomona and Taumaranui districts.	15			15	25		1145	
70		35			70	185		130	15
71		10			480	100		280	
72					280			10	
73		60			20	10		480	
74					10	5	5	255	
75		20			50	5		170	
76		15			5	5		265	
77		15			5			190	
78		15				5		1150	
79		15			105	5		485	
80		10						40	
81		27						530	
82	Hill pastures in regions with medium summer rainfall; Te Awa and South-Hawkes Bay districts.	10(b)						120	
83		10(b)						220	
84		15(b)						280	
85		30			5	5	30	240	
86		10					10	230	
87								670	
88	Hill pastures in regions with low summer rainfall; Wairarapa and Hawkes Bay districts.		10				95	1365	75
89		5					45	1060	790
90								730	1760
91							5	840	25
92					5		5	420	55
93						100		1110	1270
94		5					885	295	45
95								940	480
96		5						180	560
97								160	290
	Te Awa hill pastures sampled in 2 consecutive years.								
98	Unimproved pasture continuously grazed:								
	Sampled 1950	10						265	
	Samples 1951	10						240	

Table III. (Contd.)

Field No.	Characteristics of the areas	Number of seeds per square foot							
		White Clover	Red Clover	Strawberry Clover	Lotus major	Lotus hispidus	Subterranean Clover	Suckling Clover	Other * annual Legume species
99	Unimproved pasture, grazed except between December 1950 and April 1951:								
	Sampled 1950	5						245	
	Sampled 1951	50						430	5
100	Pasture previously oversown with legumes and fertilized with superphosphate; continuously grazed:								
	Sampled 1950	10						275	
	Sampled 1951	15					20	240	5
101	Pasture previously oversown with legumes and fertilized with superphosphate, grazed except between December 1950 and April 1951:								
	Sampled 1950	10						305	
	Sampled 1951	580	10		70		20	1500	10

Field No.	Characteristics of the areas	Gorse	Broom	Goat's rue	Tree Lucerne	White Clover	Suckling Clover
102	Pastures invaded by shrubby legumes	2740					70
103			5280				140
104				480		25	
105					1095		

(a) Content of cyanophoric glucoside high

(b) Content of cyanophoric glucoside low

* Including clustered clover Trifolium glomeratum, knotted clover T. striatum, haresfoot trefoil T. arvense, hop trefoil T. campestre, English trefoil Medicago lupulina, burr clover M. hispida.

TABLE IV. RESULTS OF GERMINATION TESTS ON DORMANT LEGUME SEEDS FROM SOIL SAMPLES AFTER SCARIFICATION OF THE SEED

Species	Germination (%)	Seeds remaining impermeable (%)
Trifolium repens	98	2
T. subterraneum	99	0
T. pratense	97	2
T. fragiferum	99	0
T. dubium	95	5
T. glomeratum	93	7
T. striatum	100	0
T. arvense	90	9
Lotus hispidus	91	9
L. major	93	6
Medicago lupulina	94	6
M. arabica	91	7
Galega officinalis	92	5
Ulex europeus	99	0
Cytisus scoparius	100	0
C. proliferus	83	17

DISCUSSION

The present work was in the nature of a general survey of the occurrence of legume seed in New Zealand pasture soils. In order that as many fields as possible could be included sampling was not usually repeated. Where replicate samples were taken the coefficient of variation of the number of seeds in a sample of 100 cores was approximately 22.5 per cent. A soil borer of small diameter was used so that each sample might comprise many small cores. It was expected that this precaution would reduce the effect upon the variability of the sample of uneven distribution of seeds within a field. The soil was sampled down to a depth of only 2 in. because it appeared most unlikely that seeds buried more deeply would be of any significance in natural regeneration in permanent pastures. Murphy and Arny (1939) and Moore (1943) have shown that white clover and red clover seedlings fail almost completely to emerge when seeds are sown 2 in. deep even in light soils.

The results in Table III show that dormant legume seeds have a very wide distribution in agricultural soils in New Zealand. The quantity of such seed present in soil is often many times that which a farmer would sow to obtain a dense stand. Thus, Area 63 contained white clover seed equivalent to 250 lb of seed to the acre, while Area 44 contained subterranean clover seed equivalent to 735 lb of seed to the acre. The density of the seed population in some of the areas greatly exceeded the highest recorded by workers elsewhere; for example, white clover seed in Area 63 was present at the rate of approximately 200 million seeds per acre. However, valid comparisons cannot be made because of the differences in technique. In the present work, all seeds in the soil samples were extracted and counted, whereas other workers have counted only those seeds which germinated within a limited time, usually less than 2 years.

Almost all the legume seeds were in the impermeable condition when recovered from the soil samples, and it is concluded therefore that very shortly after becoming permeable the seeds either germinate or decay. Had the samples been taken during summer months there might have been a larger proportion of permeable clover seeds, for it has been shown by Toole and Hollowell (1939), Burton (1940), and Blaser and Killinger (1950) that the germination of such seeds is inhibited by high soil temperatures. Almost all the dormant legume seeds recovered from soil germinated readily when scarified, indicating that legume seeds rarely lose their viability while they remain in the impermeable condition in the soil.

The legume species represented in the seed population of the soil were generally present also in the vegetation of the area, as might be expected since most of the areas had been in pasture of fairly uniform composition for many years. Areas 102 and 103 were exceptional, in that clover seed occurred where no clovers were growing, but in these areas there had been a recent change in the vegetation involving the disappearance of pasture and the establishment of pure stands of shrub species.

It is assumed that the main factors determining the density of the seed population of soil are the rate of replenishment and the duration of dormancy. In pastures replenishment of the dormant seed may be

prevented by close grazing. The population of white clover seeds under pastures where this species was abundant varied according to the degree to which the management of the pasture permitted the ripening of seed. Lowland pastures which were closely grazed by sheep and in which white clover could rarely produce seed (Areas 37 to 41) contained an average of 51 seeds per square foot. Similar pastures grazed by cattle (Areas 23 to 36) contained an average of 187 seeds per square foot, whereas fields which had been closed for seed crops (Areas 1 to 8) contained an average of 1037 seeds per square foot. These figures are, of course, subject to sampling errors, but reference to the criteria of Table II shows that all differences here are highly significant. The importance of opportunity for reseeding is still more apparent with red clover. Seeds of this species occurred rarely except in fields which had been closed for seed crops.

The increase in the number of seeds of suckling clover in Areas 99 and 101 when grazing was discontinued shows that, with annual species also, intensity of grazing is a factor determining the seed population; but in general the seed population of annual legumes varied in accordance with soil type and rainfall rather than with intensity of grazing. The annual species abound where summer droughts check the growth of perennials and leave open ground on which seedlings readily establish after autumn rains, and it was on such areas that the highest seed populations of annual species were recorded. In pastures on fertile land (Areas 23 to 41) the average number of seeds of annual species was 37 per square foot, whereas in pastures on light dry land (Areas 42 to 51) the average number was 1870 per square foot.

Since it is known that dormancy sometimes persists for many years, it might be expected that the age of a pasture would be a factor determining the seed content of the soil, but there was no correlation between age and seed content. Any effect of age is generally masked by other factors.

It appears that seed dormancy in legumes constitutes a biological advantage because it results in seedlings emerging successively, and in their continuing to emerge for many years though the production of new seed be prevented. Seed dormancy improves the chances of a species persisting in localities where seasons unfavourable to seed production occur, or where conditions are rarely favourable for seedling establishment. A pasture legume which maintains itself by regeneration from seed is therefore most likely to persist where there is an abundance of dormant seeds. Recent observations on strains of *Trifolium incarnatum* support this suggestion. James and Bancroft (1951) found that the strains which have the greatest ability to volunteer are those which produce the highest percentage of impermeable seeds.

Pasture legumes vary in their dependence upon regeneration from seed. For annual species the importance of regeneration from seed is obvious. Toole and Hollowell (1939) concluded that annual legume species become valuable in range pastures only when a seed equilibrium has been established in which viable seeds are present in sufficient numbers to produce a good stand. Short lived perennials such as red clover are similarly dependent upon regeneration from seed for survival in

permanent pasture. Red clover commonly fails to persist and this may be due largely to the fact that constant grazing prevents the establishment of an adequate seed population.

White clover is capable of vegetative reproduction and in some circumstances may survive without reseeding. Chippendale and Milton (1934) concluded that in hill pastures in Wales, white clover survived almost entirely through vegetative reproduction. Under very different climatic conditions in Georgia, Burton (1940) found white clover to behave as a winter annual and to be entirely dependent upon regeneration from seed. The present survey shows that in most New Zealand soils, white clover seeds occur in numbers sufficient to suggest that regeneration from seed could be an important factor in the persistence of this clover in permanent pastures.

The observations on Area 101 show that in a pasture the population of dormant seeds can be greatly increased in a single year if there is a sufficient stand of clover and if grazing is relaxed to permit the plants to ripen seed freely. The possibility of maintaining a strong stand of clovers during many years of continual close grazing by first permitting a large population of dormant seeds to accumulate is worth investigating, especially on land where clovers can be introduced into pastures by oversowing, but where in the past they have failed to persist. Where natural regeneration of white clover is relied upon for pasture improvement, it is important the the dormant seeds should represent good agronomic strains. Good strains identifiable by their cyanoglucoside content (Doak, 1935) were found to predominate in the dormant seeds from some localities (Table III, Areas 1 to 5) and very poor strains in seed from other localities (Areas 82 to 84).

The technique used in this work for extracting seed from soil samples may have some use in agriculture. The authors who have used the same methods to determine the populations of common weed seeds in soil and have found it satisfactory for all except the smallest seeds such as those of *Juncus* Spp. and *Bartsia viscosa*. A knowledge of the seed content of soils could provide a measure of the effectiveness of fallows and cultivation for weed control, and could serve as a guide in selecting weed free soils for the preparation and renovation of fine turfs. Where pedigree white clover seed crops are to be grown on new areas, it should also be possible to assess the risk of contaminating the crop with inferior volunteer white clover or with troublesome foreign species such as suckling clover.

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REFERENCES

BLASER, R. E. and KILLINGER, G. W. (1950): Life history studies of Louisiana White Clover. *Agron. J. 42,* 215-20.

BRENCHLEY, W. E. (1918): Buried weed seeds. *J. Agric. Sci. 9,* 1-31.

BRENCHLEY, W. E. and WARRINGTON, K. (1930): The Weed Seed Population of Arable Soil. Pt. I. *J. Ecol. 18,* 235-72.

——— (1933): The Weed Seed Population of Arable Soil. Pt. II. *Ibid. 21,* 103-27.

——— (1936): The Weed Seed Population of Arable Soil. Pt. III. *Ibid. 24,* 479-501.

——— (1945): The Influence of Periodic Fallowing on the Prevalence of Viable Weed Seeds in Arable Soil. *Ann. App. Biol. 32,* 285-96.

BURTON, G. W. (1940): Factors Influencing the Germination of Seed of *Trifolium repens. J. Amer. Soc. Agron. 32,* 731-8.

CHAMPNESS, S. S. (1949): Note on the Technique of Sampling Soil to Determine the Content of Buried Viable Seeds. *J. Brit. Grassland Soc. 4,* 115-8.

CHAMPNESS, S. S. and MORRIS, K. (1948): The Population of Buried Viable Seeds in Relation to Contrasting Pasture and Soil Types. *J. Ecol. 36,* 149-73.

CHIPPENDALE, H. G. and MILTON, W. E. J. (1934): On the Viable Seeds Present in the Soil Beneath Pasture. *J. Ecol. 22,* 508-31.

DOAK, B. W. (1935): Cyanoglucosides in White Clover. *N.Z. J. Agric. 51,* 159-62.

EWART, A. J. (1908): On the Longevity of Seeds. *Proc. Roy. Soc. Vict. n.s. 21 (1),* 1-203.

FOY, N. R. and HYDE, E. O. C. (1937): Investigation of the Reliability of the "Picric Acid Test" for Distinguishing Strains of White Clover in New Zealand. *N.Z. J. Agric. 55,* 219-24.

GOSS, W. L. (1944): Vitality of Buried Seeds. *J. Agric. Res. 29,* 349-362.

HARRINGTON, G. T. (1916): Agricultural Value of Impermeable Seeds. *J. Agric. Res. 6,* 761-97.

JAMES, E. and BANCROFT, T. A. (1951): The Effect of Calcium, Phosphorus and Potassium on the Production of Hard Seed in Crimson Clover. *Agron. J. 43,* 96-98.

LEGGATT, C. W. (1931): Further studies on the Hard Seed Problem: Alfalfa and Sweet Clover. *Sci. Agric. 11,* 418-27.

MILTON, W. E. J. (1936): The Buried Viable Seeds of Enclosed and Unenclosed Hill Land. *Welsh Plant Breeding Station Bull. Series H.* No. 14.

——— (1943): The Buried Viable Seed Content of a Midland Calcareous Clay Soil. *Emp. J. Exp. Agric. 20,* 155-66.

MOORE, R. P. (1943): Seedling Emergence of Small Seeded Legumes and Grasses. *J. Amer. Soc. Agron. 35,* 370-81.

MURPHY, R. P. and ARNY, A. C. (1939): The Emergence of Grass and and Legume Seedlings Planted at Different Depths in Five Soil Types. *Ibid. 31,* 17-28.

TOOLE, E. H. and HOLLOWELL, E. A. (1939): Effects of Different Temperatures on the Germination of Several Winter Annual Species of Trifolium. *Ibid. 31,* 604-19.

STOA, T. E. (1933): Persistence of Viability of Sweet Clover Seed in Cultivated Soil. *Ibid. 25,* 177-81.

TREATMENT OF A LIME-INDUCED MANGANESE DEFICIENCY IN PEACH TREES

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Summary

Peach trees in the Hawke's Bay district showing symptoms of manganese deficiency were subjected to various treatments, including the application of manganese sulphate in sprays, by placement round the roots, or by solid injections, and the acidification of the soil by applications of sulphur. The effect of the treatments was followed by leaf and soil analyses. The results indicated that: :

(1) Manganese sulphate sprays were completely effective in preventing deficiency symptoms.

(2) Spraying was effective for the season of application only.

(3) Manganese sulphate, sulphur, or manganese sulphate + sulphur, added to the top 6-in. of soil was in general unsuccessful in correcting manganese deficiency in peach trees.

(4) Placement of manganese sulphate about the roots was only partly successful and was effective for one season only.

(5) Sulphur was effective in reducing soil pH but on this soil an increase to the original high level appears to be in progress.

(6) Solid injection of manganese sulphate increased the manganese content of the leaves and prevented deficiency symptoms.

Introduction

Chlorosis of peach trees in Hastings was reported by Atkinson[1] in 1944 and was, on the basis of typical symptoms and response to manganese sprays, diagnosed as due to a deficiency of manganese.

In the 1947-48 season, as a result of the extremely dry soil conditions, manganese deficiency symptoms became much more prevalent throughout the district, and it was at this stage that the Soil Bureau, at the request of the Plant Diseases Division, undertook to carry out soil investigations.

Although no detailed survey of the extent of manganese deficiency in the fruit growing area of Hastings has been made, Mr. T. Conway, District Orchard Instructor, Department of Agriculture, estimated that in a dry season when manganese deficiency symptoms are most severe, as many as 50 per cent of orchards and possibly 20 per cent of all peach and nectarine trees may be affected. Deficiency symptoms have been noted on apples, plums, quinces, and apricots, but this would be true of only a small percentage of the trees. The incidence on peach trees raises the percentage of orchards showing symptoms, since nearly all orchards in the district contain some peach trees. Manganese deficiency symptoms have been observed also on many shrubs, perennials and annuals, as well as on vegetable crops and berry-fruits.

Manganese is considered to be absorbed by the plant in the manganous form, but there are other forms of manganese, e.g., oxides of valency greater than 2, which can influence the manganese content of plants. Leeper[2] has put forward the suggestion that this fraction may

be considered "easily reducible" and that it becomes available to plants when reduced to the manganous state. The reduction seems to be due in the main to biological agencies. The factors influencing manganese availability in soils have been summarised in a "Manganese Cycle" put forward by Mann and Quastel[3].

The aim of the present investigation was to determine the soil factors responsible for the manganese deficiency and, if possible, to alter the soil conditions so as to effect a more or less permanent cure. For comparison, spray trials and a limited number of solid injections were run in conjunction with soil treatments.

EXPERIMENTAL PROCEDURE

A block of "Golden Queen" peach trees in an orchard at Pakowhai was chosen for soil and spray trials. This block was made up of 21 trees in three rows of seven. The outer rows consisted of trees approximately ten years old, but the trees in the middle row (Row P), which had previously been occupied by poplars, were only about five years old.

Soil Conditions

The soil in this orchard has been classified by the Soil Bureau[4] as the Hastings silt loam—a highly fertile soil of moderate granular structure. Soil samples of depth 0-8 in. were taken from the three rows, each sample being a composite of seven subsamples. The analyses are given in Table I.

It will be seen that while the soil from the three rows is similar in most respects, soil from Row P has a higher calcium content and pH. These differences appear to be due to liming carried out when the poplar trees were replaced by peach trees.

The manganese contents of the soils are given in Table II. The total manganese figures indicate that deficiency of manganese in the trees cannot be attributed to a lack of this element in the soil, but it would appear that the naturally high lime content of the soil from this orchard, which may have been increased by liming, has reduced the manganese available for plant growth to a deficient level.

Treatment

In each row of seven trees treatments were respectively:

(a) Sulphur
(b) Manganese sulphate
(c) Manganese sulphate + sulphur
(d) Manganese sulphate spray
(e) Manganese sulphate spray + sulphur (added to the soil)
(f) Control
(g) Control

Treatments applied throughout the experiment are given in Table III.

TABLE I. SOIL ANALYSES
(Results on the oven-dry bases)

Row	pH	P_2O_5 1% citric acid soluble (%)	C (%)	N (%)	C/N	CATION EXCHANGE					
						Exchange Capacity (m.e.%)	Total Exch. Bases (m.e.%)	Base Saturation (%)	Exchangeable Calcium (m.e.%)	Exchangeable Magnesium (m.e.%)	Exchangeable Potassium (m.e.%)
W	7.6	0.11	2.6	0.25	10	20.4	21.5	(100)	17.8	2.05	1.95
P	7.9	0.12	2.9	0.27	11	22.5	25.4	(100)	23.0	2.10	1.90
E	7.5	0.10	3.0	0.28	11	21.1	22.2	(100)	18.5	2.25	2.05

TABLE II. MANGANESE CONTENT OF SOIL
(Results on the oven-dry basis)

Row	Manganese present		
	Total (p.p.m.)	Exchangeable (p.p.m.)	Easily Reducible (p.p.m.)
W	394	< 0.2	44
P	410	< 0.2	44
E	427	< 0.2	54

TABLE III. SCHEME OF TREATMENTS

Treatment	Row	1948-49	1949-50	1950-51
Sulphur Applied (kg.)	W	1.10	1.10	—
	P	2.32	1.45	—
	E	0.73	0.73	—
Manganese Sulphate Applied (g.)	W	510	510	—
	P	510	510	—
	E	510	510	—
Manganese Sulphate Spray (%)	W	0.2	0.3*	0.3*
	P	0.2	0.3*	0.3*
	E	0.2	0.3*	0.3*

* Wetting agent ("Agral L") included.

Truog[5] considers pH 6.5 to be the critical level, below which increased amounts of manganese should become available. In this work, sulphur was added, after laboratory tests, in amounts calculated to reduce the pH to 6.0.

Manganese sulphate was added in amounts designed to raise the level of "easily reducible" manganese in the same volume of soil to approximately 100 p.p.m., assuming all the manganese added to be retained in this fraction.

Both the sulphur and the manganese sulphate were spread over a circle of 6-ft. radius around the tree and mixed with the soil to a depth of about six inches. Soil treatments were applied in early spring, while spraying was carried out shortly after the petal-fall stage.

Treatments were arranged in a random manner with the proviso that no two adjacent trees were given the same treatment.

Analytical Methods

Manganous manganese is held in the soil as "exchangeable manganese" and is usually determined by extraction with normal ammonium acetate adjusted to pH 7.0. "Easily reducible" manganese is determined by extraction with normal ammonium acetate (pH 7.0) together with a reducing agent such as hydroquinone or hydroxylamine, following extraction of the exchangeable manganese. Leeper[2] considers that there is as yet no analytical method which can distinguish between healthy and deficient soils in the neutral or slightly alkaline range without admitting of some exceptions. He merely claims that the estimation of easily reducible manganese lessens the number of exceptional cases which would occur if only the exchangeable fraction were considered.

In the present work, exchangeable manganese was determined by shaking 20 g of soil at field moisture with 200 ml of normal ammonium acetate (pH 7.0) for 30 min. After centrifuging, the supernatant liquid was removed and the soil shaken for a further 30 min. with 200 ml of normal ammonium acetate (pH 7.0) containing 0.2 per cent hydroxylamine, to determine the easily reducible fraction. "Available" manganese comprises the exchangeable and the easily reducible forms.

The organic matter in the soil extracts or the leaf samples was destroyed by wet digestion, and the manganese determined as described by Willard and Greathouse[7]. Since, in the exchangeable manganese and leaf manganese determination, small amounts of manganese were being estimated in the presence of comparatively large amounts of calcium, it became necessary to separate the calcium before development of the permanganate colour. In this way excessive amounts of calcium sulphate were avoided when making up to volume—usually 5 ml. This was done by precipitating the calcium as calcium sulphate in 50 per cent ethyl alcohol. Complete recoveries of 20 and 100 μg quantities of manganese were obtained when 450 mg. of calcium acetate were separated in this manner.

Determinations of pH were made in the laboratory with the glass electrode, using a soil : water ratio of 1 :2.5. The soil samples were the same as those used for the determination of exchangeable manganese, and were kept at field moisture for the few days which elapsed between sampling and analysis.

Sampling

For leaf analysis, approximately 100 leaves were collected from each tree, either in late January or early February. These were taken from the basal parts of the current season's growth, since deficiency symptoms were generally most marked in this position.

Soil samples (depth, 0-8 in.) were composites, made up of four subsamples, taken at a distance of 3 ft. from the trunk. Unless stated otherwise, sampling was carried out at the time leaf samples were taken.

RESULTS

Soil pH

In Table IV are given the pH values for soils to which sulphur was added in quantities shown in Table III.

These figures show that sulphur applications calculated to reduce the soil pH to 6.0 were in general successful. It was not expected that complete efficiency would be obtained under field conditions, and pH values less than 6.5 were considered satisfactory.

There is a tendency for the pH values of sulphur-treated soils to rise again, as can be seen from the figures for 5 Sept., 1949 and 3 July, 1951. This increase is probably due to the ground-water rising through high lime sediments during wet periods, (the pH of the subsoil may be over 8.0) and suggests that permanent reduction in soil pH may be impracticable. The increase in pH has occurred even when large amounts of sulphur were added over the first two seasons (approximately 1½ tons per acre, in Row P, on the area treated with sulphur).

Soil Manganese

Exchangeable Manganese: In Table V are given the changes in this fraction as a result of applications of sulphur, manganese sulphate, and manganese sulphate plus sulphur.

Although it might have been expected that reduction in pH to 6.5 or less would increase the exchangeable manganese, no marked changes were noted in this fraction over the 1948-49 season. In the second season, some increases in exchangeable manganese did take place, notably in soils treated with sulphur, and with manganese sulphate plus sulphur. With one exception (Tree P.2), these increases are small. The power of this soil to fix manganese is emphasised by the fact that if even 1 per cent of the manganese sulphate added in one season had remained in the exchangeable form, figures of approximately 1 p.p.m. would have been obtained.

TABLE IV. REDUCTION OF SOIL pH WITH SULPHUR

Trees	Treatment	Sampling Date							
		21/9/48	18/1/49	5/9/49	8/2/50	8/11/50	7/2/51	3/7/51	21/2/52
Row W	Controls (2 trees)	7.2	7.2	...	6.7	...	...	7.1	6.7
	Sulphur (3 trees)	7.3	6.4	7.0	5.7	5.6	6.0	6.5	6.5
Row P	Controls (2 trees)	7.9	7.9	...	7.5	...	...	7.7	7.7
	Sulphur (3 trees)	7.8	6.7	6.6	6.1	6.2	6.5	6.9	6.9
Row E	Controls (2 trees)	7.4	7.3	...	6.8	...	...	7.1	6.7
	Sulphur (3 trees)	7.3	6.5	7.0	6.2	5.9	6.1	6.9	6.9
		Sulphur added 22/9/48		Sulphur added 13/9/49					

TABLE V. EFFECT OF SULPHUR AND MANGANESE SULPHATE APPLICATIONS ON AVAILABLE MANGANESE IN THE SOIL
(Results on the oven-dry basis.)

Treatment	Tree	1949-49 Season			1949-50 Season		
		pH	Exchangeable Mn (p.p.m.)	Easily Reducible Mn (p.p.m.)	pH	Exchangeable Mn (p.p.m.)	Easily Reducible Mn (p.p.m.)
Control	W 4	7.2	0.2	41	6.6	0.2	41
	W 7	7.2	0.2	54	6.7	0.3	53
	E 3	7.3	0.2	45	6.6	0.2	43
	E 5	7.3	0.2	51	6.9	0.2	48
	P 1	7.8	0.2	41	7.4	0.3	40
	P 6	8.0	0.2	47	7.5	0.3	48
Sulphur	W 2	6.5	0.3	44	5.6	0.7	44
	E 6	6.6	0.2	57	6.4	0.4	54
	P 7	6.7	0.2	58	6.3	0.2	55
Manganese sulphate	W 5	7.1	0.2	70	6.5	0.3	78
	E 2	7.2	0.2	73	6.8	0.2	79
	P 4	7.8	0.3	62	7.6	0.2	77
Manganese sulphate + sulphur	W 6	6.5	0.3	75	5.8	0.6	89
	E 1	6.4	0.2	74	5.9	0.5	89
	P 5	6.5	0.4	71	6.1	0.6	97
Manganese sulphate (spray)	W 1	6.7	0.2	44	6.4	0.2	43
	E 7	7.5	0.2	56	6.8	0.3	55
	P 3	7.8	0.3	41	7.2	0.3	42
Manganese sulphate (spray) + sulphur	W 3	6.2	0.2	45	5.6	0.5	45
	E 4	6.5	0.2	49	6.4	0.3	47
	P 2	6.8	0.3	44	5.8	1.1	45

Easily Reducible Manganese: As would be expected, where manganese sulphate has been added to the soil, the easily reducible fraction has increased (Table V). Manganese sulphate was added in quantities calculated to raise the fraction by about 60 p.p.m., i.e. from about 40 to 100 p.p.m., assuming all the added manganese to appear in this form. In the 1948-49 season the increase was of the order of 30 p.p.m., i.e. only 50 per cent of the possible increase, with no difference between manganese added alone or with sulphur. Further applications in the 1949-50 season produced only one increase of an additional 50 per cent, and in one case only 12 per cent of the possible increase was obtained.

Penetration of Added Manganese: After the addition of manganese sulphate over two seasons, a check was made on the downward penetration of manganese. Depression of soil pH by sulphur should encourage such a downward movement, but as can be seen from Table VI no movement of manganese into the 9-12 in. horizon could be detected, when manganese sulphate was added with sulphur. For comparison figures are given for soil from those control trees nearest the trees which received soil applications of manganese sulphate + sulphur.

Table VI. Penetration of Added Manganese
(Results on the oven-dry basis.)

Treatment	Tree	0-8 in. depth		9-12 in. depth	
		pH	Easily Reducible Mn (p.p.m.)	pH	Easily Reducible Mn (p.p.m.)
Control	W 7	6.7	53	6.8	54
	E 3	6.6	43	7.1	38
	P 6	7.5	48	8.0	36
Manganese sulphate + sulphur	W 6	5.8	89	6.9	40
	E 1	5.9	89	7.6	44
	P 5	6.1	97	7.5	34

Tree Response

Over the three seasons visual examination indicated that, of all the treatments, sprays alone produced a response. In the first season, sprayed trees showed a marked reduction in chlorosis, whereas in the second and third seasons, removal of chlorosis was complete and the leaves were dark green in colour. The only other trees to show an improvement were P.5 and W.5 which were almost completely free of chlorosis in the 1950-51 season, and showed a marked uptake of manganese (Table VII). Trees W.6 and E.1, treated in the same way as P.5, showed no such improvement. The large increase in the manganese content of sprayed leaves in 1949-50 was due to the application of two sprays and to increased spray strength.

Trees P.3 and E.7 were left unsprayed in the 1950-51 season after having been sprayed the two previous seasons. It will be seen that no manganese was stored and carried over to the 1950-51 season (Table VII). These two trees showed chlorosis in 1950-51 although they were completely green the previous season.

At the time of leaf sampling trees were assessed according to the degree of chlorosis—from badly-chlorotic to non-chlorotic. While admitting of some exceptions, the data indicate that symptoms of deficiency are likely to appear on this variety when the manganese content of the leaves drops below 20 p.p.m.

Although no marked increase in the manganese content of peach leaves occurred with decrease in the soil pH by sulphur applications, oats grown in pots, using soil from the Pakowhai orchard with sulphur added to give a range in pH, showed a good correlation between pH and manganese uptake (Table VIII).

TABLE VII. MANGANESE CONTENT OF LEAVES
(Results on the oven-dry basis.)

Treatment	Tree	Manganese Content (p.p.m. in. Mn)		
		1948-49	1949-50	1950-51
Control (averages of 6 trees)		11	15	14
Sulphur	W 2	8	12	17
	E 6	10	14	15
	P 7	10	22	31
Manganese sulphate	W 5	10	18	55*
	E 2	10	12	26*
	P 4	—	32	19*
Manganese sulphate + sulphur	W 6	8	12	19
	E 1	10	16	26
	P 5	8	23	71
Manganese sulphate (spray)	W 1	22	73	—
	E 7	13	201	13**
	P 3	12	238	7**
Manganese sulphate (spray) + sulphur	W 3	20	212	57
	E 4	19	169	59
	P 2	11	206	63

* "Placement" of manganese sulphate in 1950-51 season.
** Not sprayed in 1950-51 season.

TABLE VIII. EFFECT OF pH ON MANGANESE UPTAKE BY OATS
(Results on the oven-dry basis.)

Soil pH	Yield per pot* (g)	Manganese content (p.p.m.)	Manganese uptake per pot mg.)
7.4**	4.3**	17**	71**
6.8	3.9	25	98
5.7	3.5	135	470

* Pot work carried out by E. J. S. Gridley.
** All figures are averages from 4 replicate pots.

Placement of Manganese Sulphate

It had been the practice in this orchard to cultivate as deep as 6 in. To check on possible root damage, in September 1949 a trench 3 ft from the trunk was dug about a 5-year-old tree just outside the experimental block. Care was taken to reduce the breaking of roots to a minimum. At this distance from the tree, roots tended to be at a depth of 12-15 in. but closer to the tree, they appeared at about 8 in. There was some evidence of root damage. While the roots were exposed, the opportunity was taken of "placing" approximately ½ lb of manganese sulphate in intimate contact with them, the manganese sulphate being first mixed with a little soil to reduce damage by burning. In the same season, an excellent

response to this placer treatment was obtained, and except for a few isolated leaves, the tree was free of chlorosis. The manganese content of leaves from this tree was 29 p.p.m., while leaves from an adjacent control tree, which was very chlorotic, contained only 9.5 p.p.m.

The lack of response to the soil treatments as originally laid down, and the improvement from placed manganese sulphates suggested that for the 1950-51 season some form of placer treatment might well be applied to the experimental block. A trench 3 ft from the trunk was dug about trees W.5, E.2, and P.4 (all previously receiving soil applications of manganese sulphate) to a depth of about 8 in. The roots were disturbed as little as possible, and a solution of manganese sulphate ($\frac{1}{2}$ lb in 4 gal of water) was allowed to penetrate to the lower roots. This operation was carried out on 8 Nov., 1950. The manganese contents of leaves from these trees are given in Table VII.

Only one of the trees (W.5) showed a visual response, and this was the only tree to show the increase in manganese to be expected from this placement. Further, the tree which showed such a striking improvement to placer treatment in the 1949-50 season was chlorotic again in the 1950-51 season, and this was associated with a sharp drop in manganese content from 29 p.p.m. (1949-50) to 9.6 p.p.m. (1950-51). It appears that comparatively large amounts of manganese sulphate, even when localised about the roots, are rendered unavailable after one season. This result, associated with the poor response to manganese sulphate solutions poured in about the roots shows that even placed manganese is of doubtful value.

Solid Injection

Early in November 1950, a severely chlorotic peach tree, probably one of the worst in the district, was injected with manganese sulphate. This tree had two main leaders shaped like the letter Y, and one of the leaders was injected with 6 g manganese sulphate, 12 in. above the junction, after the method of Thompson[8]. The results were most striking, leaves on the injected side being green and healthy, while the control half was so chlorotic as to be almost completely yellow.

Athough no attempt was made to compare yields the orchardist, who has had experience in experimental work, noted that fruit-set and the size of fruit were strikingly improved on the injected side. In the following season, the leaves from the injected limb were a healthy green colour while those from the uninjected limb were chlorotic. Analyses for the two seasons following the injection are given in Table IX.

Table IX. Manganese Content of Leaves from Injected and Uninjected Branches (Injected, November 1950)

Date of Sampling	Manganese Content (p.p.m. Mn)	
	Uninjected	Injected
6 Feb.,1951	3.0	93
24 Feb., 1952	6.8	68

DISCUSSION

It has been suggested by Sherman and Harmer[9] that healthy soils usually contain about 3.3 p.p.m. of exchangeable manganese and about 100 p.p.m. of easily reducible manganese. On this basis, the soil from the orchard at Pakowhai is low in available manganese with figures of less than 0.2 p.p.m. and approximately 50 p.p.m. for the exchangeable and easily reducible fractions respectively. This is true also of soil samples taken from two other soil types used for orchards in this area (Table X).

TABLE X. AVAILABLE MANGANESE IN OTHER HASTINGS SOILS
(Results on the oven-dry basis.)

Soil type	pH	Exchangeable Mn (p.p.m.)	Easily Reducible Mn (p.p.m.)
Twyford Silt Loam	6.5	0.3	19
Kaiapo Clay Loam	6.5	0.3	42
Hastings Silt Loam	6.9	0.2	44

In contrast to crop or pasture plants, the difficulty with trees in correcting trace element deficiencies by soil applications is to obtain sufficient penetration of the added chemicals to the roots. This is shown by the failure of trees to respond to soil applications of manganese sulphate and sulphur, even when these were added in amounts as high as 900 lb per acre and 1½ tons per acre respectively, assuming the rate of application to be the same as on the circle treated. Analyses emphasise the rapid fixation of added manganese and the lack of downward penetration. A factor which may have reduced response to manganese sulphate and sulphur was root damage due to deep cultivation carried out by the orchardist—at its deepest, probably 6 in. This was discovered at the end of the 1948-49 season, but since then cultivation has been limited to 3 in.

It must be pointed out that while uptake of manganese in oats, when grown in pots, increased with decrease in pH, no marked changes in the fractions of soil manganese at similar pH values took place in the field. Other workers have also noted that "available" manganese is not always a reliable guide to uptake.

Placement of manganese sulphate is not easily achieved and appears to be effective for one season only. For efficient control of manganese deficiency in the Hastings fruit growing area, yearly spray treatments, or possibly solid injections, are required. No doubt the orchardist will favour yearly spraying as the simplest remedy, and it seems possible that by including manganese sulphate in appropriate amounts in the lime-sulphur spray applied shortly after petal-fall stage, the trouble could be eliminated without increasing the number of sprays in a season. This is a matter for trial, however, and it may prove to be more efficient to apply the manganese sulphate in a separate spray treatment.

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REFERENCES

1 ATKINSON, J. D. (1944): *Orchardist of N.Z. 17 (11)*: 8.

2 LEEPER, G. W. (1947): *Soil Sci. 63*: 79-94.

3 MANN, P. J. G. and QUASTEL, J. H. (1946): *Nature, 158*: 155-6.

4 N.Z. Dep. Sci. Ind. Res. (1939): Land Utilization Report of the Heretaunga Plains. *N.Z. Dep. Sci. Ind. Res. Bull. 70.* 111pp.

5 TRUOG, E. (1948): *Soil Sci. 65*: 1-7.

6 JONES, L. H. P. and LEEPER, G. W. (1950): Science, 111: 463-4.

7 WILLARD, H. H. and GREATHOUSE, L. H. (1917): *J. Amer. Chem. Soc. 39*: 2366-77.

8 THOMPSON, S. G. (1944): *East Malling Res. Sta. Ann. Rep.*, pp. 119-23.

9 SHERHERMAN, G. D. and HARMER, P. M. (1942): *Proc. Amer. Soc. Soil. Sci. 7*: 398-405.

PEA SEED DISINFECTION: A Statistical Study

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Summary

Treated peas, variety William Massey, were sown in the field on successive occasions from spring to autumn during several crop seasons. Statistical analyses of transformed data revealed significant differences between sowing dates in the emergence counts obtained. After some mid-summer sowings, untreated seed germinated as well as any disinfected line, whereas after some autumn sowings all treatments were significantly better than untreated. Over all sowing dates, tetramethyl thiuram disulphide (Premasan) and tetra-chlor-p-benzoquinone (Spergon) were highly effective in improving field emergence. The locally supplied organic mercury dusts and the used-oil treatment produced little benefit, although in an experimental set, dusts with twice the normal mercury content were effective. In a glasshouse pot trial, soil moisture was found to have a greater influence on emergence than temperature.

Introduction

Reviews by Croxall and Ogilvie (1942), McNew (1944) and Leukel (1948) all point to the efficacy of some fungicides in reducing pre-emergence losses of peas caused by a composite soil fungus population. A number of fungicides recommended overseas have not been procurable in commercial quantities in New Zealand, and reliance has been placed on the organic mercurial dusts—Agrosan and Ceresan—which Hyde (1939) found to be effective. Other materials, including copper carbonate, copper oxychloride, cuprous oxide and tetra-chloro-p-benzoquinone, have been used in field experiments by the Plant Diseases Division, Department of Scientific and Industrial Research (1942) and at Canterbury Agricultural College (1945), while Jacks (1951) found that in glasshouse and field trials, 7 of the 28 fungicides tested were considerably more effective than the remainder.

The value of pea-seed disinfection in relation to the time of sowing requires examination. Peas are sown in Canterbury, the chief New Zealand arable farming region, during the greater part of the year, in soils with a wide range of moisture and temperature conditions. In this area the results from experiments designed to test the effectiveness of organic mercurial dusts have not supported the conclusions drawn by Hyde (1939). The experiments here reported were, therefore, designed to test the readily available pea-seed disinfectants throughout the growing season, and to investigate the ineffectiveness of certain treatments.

Experimental Procedure and Results

Field Experiment A

Three replications, each of 100 sound seeds, of one untreated and six treated lines of William Massey garden peas were sown on fifteen occasions between December (summer) 1946 and May (autumn) 1948. The peas were sown in rows at 2-in. depth at approximately two-weekly intervals in the spring and summer, and at two-monthly intervals during

the autumn and winter. The field area was one which had grown various crops throughout the preceding five years.

Seed treatments were as follows:

(1) Spergon (Tetra-chlor-p-benzoquinone 98 per cent: 2 oz per bushel.
(2) Tetroc (as Spergon): 2 oz per bushel.
(3) Ceresan (Ethyl-mercury-acetate)** 2 per cent: 2 oz. per bushel.
(4) Agrosan G.N. (Tolyl-mercury-acetate)** 2 per cent: 2 oz per bushel.
(5) Copper carbonate: 52 per cent copper, equivalent to 93-94 per cent as carbonate and hydrate: 2 oz per bushel.
(6) Used tractor-crank-case oil, in a sufficient quantity to coat individual seeds with an oil film without excess.

The dust treatments were applied by shaking the requisite amount of fungicide with the seed in a closed container.

The used oil and seed were mixed carefully by hand to ensure that there was no excess of oil. This treatment in its present form has not proved satisfactory in commercial practice, where seed is drilled with fertilizer, because oiled seed and fertilizer tend to bind together causing blockages of the drill tubes, and uneven sowing.

To avoid damage by birds, the rows were covered with netting immediately after sowing. The number of seedlings in each row was counted at the completion of emergence.

The correlation of emergence rating with the weather conditions before and after each sowing was not possible because the available records were not sufficiently detailed.

Table I shows the differences between the total numbers of emerged seedlings from treated and untreated seed, and the percentage emergence from untreated and two groups of treated seed. The column of variance ratios shows that in 8 of the 15 sowings there were no significant differences between treatments. In some cases this was due to large differences between the three counts of the same treatment; in others, notably the sowing at 17/12/47, there was little variation over all counts.

TABLE I. EMERGENCE OF PEA SEEDLINGS FROM TREATED AND UNTREATED SEED
Field Experiment A2 - 300 seeds sown

Sowing Dates	No. of seedlings from untreated seeds	Differences between numbers of seedlings emerging from untreated seeds and from seeds treated with fungicide indicated						Percentage Emergence			Variance Ratios
		(1) Spergon	(2) Tetroc	(3) $CuCO_3$	(4) Oil	(5) Agrosan	(6) Ceresan	Untreated	Treatments (1)-(4)	Treatments (5) & (6)	
13/12/46	205	+9	+14	-10	+1	-22	-30	68.3	69.5	59.7	1.76
16/1/47	147	+15	+18	+13	-25	+5	+5	49.0	50.8	50.7	5.62
20/3/47	251	+16	-6	-7	-12	-10	-2	83.7	82.9	81.7	2.0
20/5/47	160	+69	+72	+75	+42	+35	+21	53.3	74.8	62.7	38.55
4/8/47	150	+26	+23	+5	+24	+8	-6	50.0	56.5	50.3	2.80
16/10/47	198	+46	+23	+34	-9	+16	+14	66.0	73.8	71.0	2.37
11/11/47	179	+62	+38	+52	+36	+3	+10	59.7	75.3	61.8	17.61
28/11/47	248	-1	+10	-15	+2	=	-39	82.7	82.3	76.2	4.77
17/12/47	249	-5	-6	-4	-4	-28	-20	83.0	81.4	75.0	1.10
8/1/48	155	+54	+80	+45	+13	+5	=	51.7	67.7	52.5	9.56
28/1/48	229	+13	+12	+10	+9	-7	-9	76.3	80.0	73.7	2.86
24/2/48	160	+83	+67	+29	+30	+7	+19	53.3	70.8	57.7	13.89
11/3/48	267	+15	+14	+9	-15	-20	+10	89.0	90.9	87.3	3.41
8/4/48	271	+12	+5	+3	-3	+3	-20	90.3	91.8	87.5	1.54
6/5/48	267	+7	+10	+6	-10	-6	-9	89.0	90.1	86.5	2.55
Totals:	-	+421	+374	+245	+79	-11	-56	69.7	75.9	68.9	

(**Pre-treated with graphite to improve adhesion).

Analysis of Results: The average number of emerged seedlings per 100 seeds sown varied between sowing dates but was, in general, above 70 per cent. Hence the arc sine transformation was applied to the raw data before analysis. Bartlett's test for homogeneity showed that the data from the several sowings could be combined in one analysis of the whole experiment. The method is explained by Snedecor (1946).

Table II shows how the variances of the dust treatments and their interactions with sowing dates were split up to give six independent comparisons, corresponding to the six degrees of freedom available for treatments.

The comparisons were chosen to demonstrate as many effects as possible and as they were largely chosen on the data rather than before examining the results, the analysis for this reason may slightly exaggerate the significance of the first two comparisons. This is not serious as they are both highly significant.

TABLE II. ANALYSIS OF VARIANCE OF TRANSFORMED DATA
(from Field Experiment A)

Variance due to:	Deg. F.	Mean Square
Replications	30	48.6
Dates	14	1551.6
Spergon + Tetroc v other 5	1	1856.7
$CuCO_3$ v other 4	1	480.6
Oil v other 3	1	24.9
Untreated v other 2	1	5.6
Agrosan v Ceresan	1	4.1
Spergon v Tetroc	1	33.6
	6	401.0
Spergon + Tetroc v other 5 with dates	14	37.9
$CuCO_3$ v other 4 with dates	14	25.4
Oil v other 3 with dates	14	39.8
Untreated v other 2 with dates	14	19.3
Agrosan v Ceresan with dates	14	24.1
Spergon v Tetroc	14	17.1
Interactions	84	27.3
Pooled Error	180	11.1
	314	

The analysis of variance shows that the difference between Spergon and Tetroc taken together, and the five other treatments (including no dust) is highly significant. Unfortunately, it was not possible in this analysis to make an independent comparison of copper carbonate with Tetroc or Spergon without sacrificing information on other com-

parisons.* The difference between oil and the other three treatments is not significant, but the interactions of Spergon and Tetroc, copper carbonate and used oil with sowing dates, are highly significant. These significant interactions suggest that there is a critical balance between soil moisture and temperature and the effect of the treatment. The difference between Ceresan and Agrosan, and Untreated, was negligible in this experiment. The two independent comparisons corresponding to the two remaining degrees of freedom are Spergon v Tetroc and Agrosan v Ceresan; neither of these differences is significant—the pairs of treatments being similar products of different manufacturers. The results emphasize the value of the tetra-chloro-p-benzoquinone preparations, and the inadequacy of the locally used dusts in which an organic mercury salt is the active ingredient.

From some sowing dates, e.g. 17/12/47, the untreated control germinated as well as any of the disinfected lines. Conversely, after the 20/5/47 sowing, all treatments were significantly better than untreated. Under the conditions which existed in the field after that sowing, oil and the organic-mercurials which, over the whole period, were inferior, did effect an improvement in field germination.

Soil moisture and temperature, two of the environmental factors which could be expected to contribute largely to the interaction between treatment and conditions at the time of sowing, were studied in the following experiment:

Pot Experiment B

Three weeks before sowing, separate lots of William Massey and Blue Prussian peas were treated, by shaking for 5 min in a closed container, with Agrosan G.N., copper carbonate, and Spergon as used in Experiment A. In addition, cuprous oxide, at 2 oz per bushel, was used.

One kilogram of garden soil, unsterilized, air dried and sieved through a 2-mm mesh, was weighed into each pot. The soil moisture content of individual pots was adjusted to 50, 70 and 96 per cent of the measured water holding capacity (48.65 per cent).

Ten sound seeds were sown in each of four pots for all combinations of variety, treatment and soil moisture content. Two temperature levels were obtained by placing two pots of each combination in random position in a glasshouse and the remainder in an open-walled, but roofed, insectary.

Over the period of observation the temperature ranged as follows:

High level	Mean Max.	84°F.	Range 55-116°F.
	„ Min.	50	42-56
Low level	„ Max.	57	44-69
	„ Min.	43	34-52

Moisture losses were adjusted daily by weighing and adding fresh water.

*The t-test (invalid) for the comparison of copper carbonate with Spergon and with Tetroc gave $t = 4.14$ and $t = 2.73$, which suggest that the difference is significant. For a valid test $t = 2.145$ at 5 per cent level of significance.

Emergence counts shown in Table III were made two weeks after the first appearance of seedlings. At high temperature level, first appearance was at 14 days after sowing, and at low temperature, 25 days after sowing.

TABLE III. EMERGENCE COUNTS (POT EXPERIMENT B)

Fungicide Used	Plants emerging at high temperature at w.h.c. indicated						Plants emerging at low temperature at w.h.c. indicated						Total
	W. Massey			Blue Prussian			W. Massey			Blue Prussian			
	50%	70%	90%	50%	70%	90%	50%	70%	90%	50%	70%	90%	
Cuprous oxide	15	14	0	16	14	4	16	15	4	15	14	12	139
Spergon	7	9	1	14	11	4	16	8	3	13	13	7	106
Copper carbonate	12	8	1	14	10	10	13	10	2	14	18	6	118
Agrosan	5	1	0	13	8	2	7	8	0	12	8	4	68
Untreated	9	3	0	7	2	0	6	1	0	11	6	2	47
Totals	48	35	2	64	45	20	58	42	9	65	59	31	478

Because only ten peas were sown in each pot, the arc sine transformation was again used before analysis of variance (where no seeds germinated the angle 0.1° was used).

In order to compare the two experiments the variances (Table IV) were apportioned to individual degrees of freedom as in the field experiment.

TABLE IV. ANALYSIS OF VARIANCE OF TRANSFORMED DATA (POT EXPERIMENT B)

Variance due to:	Deg. F.	Mean Square
CuO v other 4	1	4182
Spergon v other 3	1	1472
$CuCO_3$ v other 2	1	5545
Agrosan v untreated	1	524
Dust treatments	4	2931
Moisture	2	10637
Varieties	1	4286
Temperatures	1	1345
Interaction CuO v other 4 with M.V.T.	11	158
" Spergon v other 3 with M.V.T.	11	86
" $CuCO_3$ v other 2 with M.V.T.	11	137
" Agrosan v untreated with M.V.T.	11	161
Interactions M.V. and T.	7	154
Within pairs of pots	60	77

The results of this experiment are in agreement with the former field trial. Cuprous oxide, Spergon and Copper Carbonate gave significant increases in the number of emerging seedlings. There was no significant difference between Agrosan and Untreated.

The main effects of soil moisture, temperature and variety are all highly significant.

Table III shows that the highest emergence was obtained from seed treated with the effective dusts grown in soil at 50 per cent of saturation and held at the lower temperature level. The appendices in Jacks' paper (1951) show that, although some dusts were effective at the three levels, viz. 25, 45 and 65 per cent w.h.c., the maximum benefit from the more effective dusts was derived at 45 per cent w.h.c. The range 45-50 per cent w.h.c. would not be looked upon as "wet" soil, although it is the popular belief that maximum benefit is obtained from the use of fungicidal dusts when peas are sown in very wet soils. Soil temperature in this experiment had an influence on the number of emerging seedlings (Table III), but not to the extent reported by Ledingham (1946), who concluded that pea emergence was more strongly correlated with soil temperature than with soil moisture.

Field Experiment C

The lay-out was identical with that of Experiment A, but with seven sowings made between 7 September, 1950 (spring) and 22 February, 1951 (summer). Among the dust treatments, however, comparisons were made with Spergon, previously shown to be promising, and a proprietary line of tetramethyl-thiuram-disulphide—Premasan. In addition, some experimental dusts provided by Bayer Products Ltd. were used which contained a range of organic-mercury content. The latter were used to see whether the ineffectiveness of organic-mercurial fungicides demonstrated in the previous trials was due to a low concentration of the active ingredient.

Table V shows the differences between treated and untreated seeds in numbers of emerged seedlings.

TABLE V. EMERGENCE OF PEA SEEDLINGS FROM TREATED AND UNTREATED SEEDS
Field Experiment C - 300 seeds sown

Sowing Dates	No. of seedlings from untreated seeds	Differences between numbers of seedlings emerging from untreated seeds and from seeds treated with fungicide indicated							Percentage emergence		Variance Ratios
		Serfolex (containing organic Hg)					Premasan	Spergon	Untreated	Spergon	
		0.5%	1%	2%	3%	4%	T.M.T.D.				
7/9/50	171	+17	+39	+23	+57	+27	+13	+69	57.0	80.0	3.34
5/10/50	181	+22	+38	+42	+42	+65	+56	+72	60.3	84.3	3.53
15/11/50	187	+15	+15	+19	+21	+27	+56	+57	62.3	81.3	22.87
14/12/50	142	-26	+22	+26	+57	+74	+49	+42	47.3	61.3	8.12
15/1/50	185	-32	-18	-11	+27	+43	+53	+53	61.7	79.3	59.88
2/2/51	179	+20	+22	+36	+44	+48	+60	+61	59.7	80.0	4.16
22/2/51	247	-23	-12	+10	+5	-4	+21	+9	82.3	85.3	2.18
Totals:	1292	-7	+106	+145	+253	+280	+308	+363	61.5	78.8	

Since each count was based on 100 seeds sown, the arc sine transformation was again used before analysis of the data. Bartlett's test for homogeneity of variances showed that the data from the third and fifth sowings could not be included in a combined analysis. The analysis of variance of the transformed emergence counts for the remainder of the sowings is presented in Table VI. Seven independent comparisons of the dust treatments were possible, corresponding to the seven degrees of freedom available. The selection of the comparisons to be tested was influenced by the results of the preceding experiments. Four of the five Serfolex treatments were at equally spaced levels. It was, therefore, possible to make a straightforward test for linearity of response to increasing applications of Serfolex. It was decided to compare Serfolex 0.5 per cent with the control treatment.

TABLE VI. ANALYSIS OF VARIANCE OF TRANSFORMED DATA FROM FIELD EXPERIMENT C
(Sowings 1, 2, 4, 6, 7)

Variance due to:	Deg. F.	Mean Square
Replications	10	
Sowing dates	4	858.8
Untreated v Serfolex 0.5% (Untr. + Serf.½)	1	.9
Serfolex 1, 2, 3, 4%	1	865.7
Linear component	1	176.4
Departure from Linearity	2	15.1
TMTD v Spergon	1	36.6
(TMTD + Spergon) v other treatments	1	578.4
Dust treatments	7	239.0
Interaction of Treatment with sowing dates	28	31.3
Pooled Error with sowing dates	70	17.7
	119	

The analysis of variance (Table VI) shows that there were again highly significant differences between the times of sowing in emergence counts over all treatments. The response to dust treatments was in agreement with the results of the previous trials, Spergon and TMTD (Premasan) being highly significantly better than other treatments. The difference between the two was not significant. The difference between untreated and Serfolex (0.5 per cent) together and the other Serfolex treatments was highly significant. The linear response to Serfolex was significant and there was no significant departure from linearity of response to increasing applications of the active ingredient over the range tested.

The results from the third and fifth sowings, omitted from the analysis, were similar to those obtained from the other sowings.

DISCUSSION

Successive field sowings from spring to autumn, throughout several years, and a greenhouse trial have shown that the tetra chlor-p-benzoquinone fungicides were more effective than the organic-mercury dusts in protecting germinating peas from fungus decay. Hutton (1944) in Australia and McNew (1943) in the U.S.A. obtained similar results. It is suggested that the Spergon type of dust is more effective than the Ceresan-Agrosan group because it has better adhesive properties and a much higher concentration of active toxic ingredient. Heavy dressings of the organic-mercury (3-4 oz per bushel) were shown by Hyde (1939) to have increased pea-seed emergence, and in the trials under report a number of formulations were used in which the organic-mercury ranged from 0.5 to 4 per cent. The 4 per cent mercury dust was effective, but its use in commercial seed-treating machines would be out of question as such a commodity would endanger the health of

machine operators. The recent commercial introduction of tetramethyl-thiuram-disulphide dust fungicides, equally as effective as higher priced tetra-chlor-p-benzoquinone (Spergon-Tetroc), has therefore been a timely development.

The variation in percentage emergence from treated and untreated seed over the 22 sowings has shown that under some conditions there is little or no improvement in germination from the use of fungicidal dusts. However, the germination in the field of untreated garden peas of the best available quality, averaged little more than 60 per cent over all sowings; whereas the over-all averages show that the field emergence from seed treated with tetra-chlor-p-benzoquinone or T.M.T.D. was at least 15 per cent higher. The real benefit which might accrue from the use of seed dusts was not demonstrated by the field experiments—not one of the sowings was followed by continued heavy rain which would have caused water logging of the soil and probable failure of the untreated seed. In Experiment B, in the soils maintained at 70 per cent of their water-holding-capacity, the difference in germination between treated and untreated seed was significant. Ledingham (1946) concluded that little or no increase in yield was to be derived from seed treatment throughout the season; but, as before, his sowings were not followed by heavy rain. The yield of a crop is influenced by the amount of moisture in the soil throughout the growing season: if germination is reasonably high, small differences in percentage emergence would not necessarily result in proportional differences in yield.

The experiments have shown that the condition of the soil for the first few days after sowing has a considerable influence on the percentage emergence of both treated and untreated seed. Under adverse conditions, the use of crtain fungicidal dusts has effected a decided improvement in germination. The disinfection of peas for all sowings would be an insurance against poor germination caused by fungus, since weather changes during the critical period are unpredictable.

REFERENCES

N.Z. DEP. SCI. IND. RES, 1942: *.N.Z. Dep. Sci. Ind. Res. 17th Ann. Rep.* p. 21.

———— 1945: *N.Z. Dep. Sci. Ind. Res. 20th Ann. Rep.* p. 69.

CROXALL, H. E. and OGILVIE, L., 1942: *Long Ashton Res. Sta. Ann. Rep.* pp. 65-72.

HYDE, E. O. C., 1939: Observations on the germination and seedling establishment of peas. *N.Z. J. Sci. Tech. A21*: 61-70.

HUTTON, E. M., 1944: The field emergence and yield of garden peas as affected by treatment of the seed with fungicidal dusts. *J. Counc. Sci. Ind. Res. Australia, 17*: 71-74.

JACKS, H., 1951: Seed distinfection I. Preliminary selection of vegetable-seed protectants. *N.Z. J. Sci. Tech. A33*: 27-38.

LEDINGHAM, R. J., 1946: The effect of seed treatment and dates of seeding on emergence and yield of peas. *Sci. Agric. 26*: 248-57.

LEUKEL, R. W., 1948: Recent developments in seed treatment. *Bot. Rev. 14*: 235-69.

MCNEW, G. L., 1943: Relative effectiveness of organic and inorganic fungicides as pea protectants. *Phytopath. 33*: 9.

————, 1944: Pea seed treatments as crop insurance. *Canner, 98*: 14-50.

SNEDECOR, G. W., 1946: "Statistical Methods," 4th Ed. Iowa State College Press, Ames.

DETERMINATION OF THE AVAILABLE MOLYBDENUM OF SOILS

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Summary

(1) Chemical methods of extracting molybdenum from soils were compared on a graded series of molybdenum-responsive soils. An acid oxalate extractant buffered at pH 3.3 was shown to give the best agreement and has been adopted for research work on pasture.

(2) From the results of observational topdressing trials it was found that responses to molybdenum applications were obtained in most of the trials where the molybdenum level was below 0.14 p.p.m. provided the pH level was below 6.3. Outside these limits there were slight responses in two cases, the other trials showing no responses.

(3) Examination of a wide range of soils indicates that large areas of marginal country are low in available molybdenum. Topdressing with amounts of 2½ oz sodium molybdate or less may mean a great increase in productivity of these areas.

(4) A field trial at Invermay Research Station showed a marked pasture response to 2½ oz sodium molybdate. Three tons of limestone gave an equal yield. Soil analyses showed that the lime had caused a significant increase in the molybdenum level of the top 1½ in. but was ineffective below this level. Applied sodium molybdate also affected only the top 1½ in. of soil.

(5) The oxalate soluble molybdenum failed to differentiate healthy and deficient soils where cauliflowers developed "whiptail". High manganese in some of the soils may account for the visual symptoms in the crops.

INTRODUCTION

In view of reports from Australia [1, 2, 3, 4, 5, 6] of responses to small topdressings of molybdenum compounds, and the widespread incidence of "whiptail"—a molybdenum deficiency—in cauliflowers in New Zealand, experiments were commenced on permanent pasture in areas where difficulty of clover establishment obtained, to discover whether molybdenum was a limiting factor. In 1946, a response occurred in Okaihau gravelly clay loam, which, however, had a higher total molybdenum content (6.88 p.p.m.) than several other soils where there was no response to molybdenum, e.g., Hamilton clay loam, 2.33 p.p.m. (Davies, E.B., unpublished data). Since total soil molybdenum appeared to have little relation to plant requirements, a chemical extractant was sought which would differentiate the fraction of soil molybdenum available to plants.

There are only two methods reported for determining available molybdenum. R. L. Mitchell [7] used neutral ammonium acetate leaching, but did not correlate the molybdenum extracted with plant requirements. This is one of the methods which have been investigated, the results being given later.

A method using the fact that minute amounts of molybdenum are essential for the normal growth of *Aspergillus niger* was published by Mulder[8] after this project was commenced. Nicholas and Fielding,[9] using this extremely sensitive method, found that soils where cauliflowers developed "whiptail" disease contained 0.01 to

0.03 p.p.m. available molybdenum, whereas healthy soils contained more than 0.50 p.p.m. Several trials of this method were unsuccessful because of the difficulty in purifying the chemicals used in the nutrient solution.

Examination of Methods Used to Measure Molybdenum Availability

In this study, molybdenum determinations were carried out by the thiocyanate - stannous-chloride method of Perrin[10]. A modification suggested by Dick and Bingley[11] was used in later determinations. This overcame interference caused by atmospheric oxidation of the large amount of ferrous-ion present. The amyl-alcohol extract of the molybdenum was shaken with 25 ml of 1:200 dilution of the stannous chloride reagent, which resulted in the bulk of the iron being returned to the aqueous phase, although the molybdo-thiocyanate complex was not affected. Molybdenum recoveries varied from 94 to 104 per cent.

The total molybdenum content of a number of New Zealand soils was found to range from 0.72 to 2.47 p.p.m. (14 samples). The Okaihau gravel loam mentioned above is exceptional, the 3 samples examined having levels of 5.00, 5.14 and 6.88 p.p.m.

Two approaches were made to the problem of finding a suitable extractant. First, methods of extraction with strong acids such as: (1) sulphuric—perchloric—nitric acid mixture; and (2) constant boiling point hydrochloric acid, were examined on five soil types where establishment and maintenance of clover pastures was difficult, although the total molybdenum level was not especially low when compared with soils carrying good pasture (Table I). Sulphuric—perchloric—nitric acid extracted from 47 to 97 per cent of the total molybdenum, while hydrochloric acid extracted a lesser amount, viz., from 11 to 67 per cent of the total. The bulk of the molybdenum in Te Kopuru sand must be held very firmly in the unweathered parent material, as only one ninth of the total was extracted by hydrochloric acid.

Table I. Extraction of Molybdenum by Strong Acids

Locality	Mo (p.p.m.) extracted by treatment with:		
	HCl + HF Treatment of SiO_2 residue="total"	H_2SO_4+$HClO_4$ + HNO_3	HCl alone
Okaihau gravelly clay loam	4.45	3.95	1.06
Taieri foothill soil (Outram)	1.65	0.66	0.48
Te Kopuru sand	0.94	0.85	0.10
Wehenga silt loam	0.81	0.78	0.58
Ngaio silt loam	0.72	0.70	0.48

As these methods gave little light on the problem, a different approach was made. This depends on the fact that there are a group of anions which have been found to be capable of mutual exchange to a greater or lesser degree when absorbed on the soil

colloid. Kurtz, de Turk and Bray[12] give the following order of strength for the replacement of phosphate ion:

F, OH > oxalate > citrate > HCO_3 > BO_3 > acetate > CNS > SO_4 > Cl.

Low and Black[13], discussing the extraction of phosphate from phosphate in a manner similar to fluoride and citrate,[14] citrate, oxalate, malate, malonate and tartrate, extracted more phosphate than anions such as acetate or benzoate which did not form complexes. Molybdate ions have been found to replace phosphate in a manner similar to fluoride and citrate.[22]

It is reasonable to consider exchangeable molybdate as the form at least potentially available for plant uptake; the amounts extracted by solutions containing oxalate, hydroxyl and phosphate ions were therefore compared. The ammonium acetate extraction of Mitchell[7] was also included in the comparison.

As there were no soils in New Zealand where pasture responses to molybdenum had actually been measured (except the response mentioned above on Okaihau gravel loam), six South Australian soils of varying response to molybdenum in field and pot trials were obtained through the courtesy of Dr. C. S. Piper, Waite Institute, Adelaide. These soils and some New Zealand soils suspected of being deficient were examined by the following extractants:

(1) Normal phosphoric acid, pH 1.2;

(2) Normal diammonium hydrogen phosphate buffered at pH 6.0;

(3) 0.1N sodium hydroxide;

(4) 0.5N (2 per cent) sodium hydroxide;

(5) Tamm's acid ammonium oxalate solution buffered at pH 3.3;

(6) N ammonium acetate buffered at pH 7.0.

In Methods 1 to 5 the soil was shaken with the buffer overnight. This period was found necessary to attain equilibrium. The solution was then filtered and an aliquot evaporated to dryness. (In the case of Methods 3 and 4, the extract was centrifuged before filtering on account of the dispersion of the soil.) The dry residue was ignited for 3–4 hr at 450°F to destroy organic matter (and ammonium salts, where present) and dissolved in 20 ml C.B.P. hydrochloric acid. From this stage, ether separation and colorimetric determination were carried out as previously mentioned.

It was necessary to extract 25 g of soil to give sufficient molybdenum for estimation. In the ammonium acetate method, the ratio of extractant to soil was 50:1. A ratio of 10:1 was used in the other methods. The results obtained were accurate to 0.4μg or 0.02 p.p.m.

COMPARISON OF RESULTS

The results obtained are given in Table II. Methods 1 and 2 using phosphate proved to be unsuitable because of analytical difficulties encountered. A yellow interference in the final amyl alcohol layer, due to the high concentration of phosphate ions, led to erroneously high results.

Table II. Extraction of Molybdenum by Different Anions
(p.p.m. Mo on air dry soil)

Locality	Total Mo	Mo extracted by method indicated*			
		3	4	5	6
South Australian Soils†					
Tooperang (1)	0.39	0.01	0.28	0.07	0.02
Kangaroo Island	1.32	0.06	0.10	0.05	0.00
Waitpinga	1.36	0.32	0.22	0.05	0.00
Lake Albert	0.24	0.02	0.07	0.05	0.00
Tooperang (2)	0.65	0.00	0.16	0.09	0.01
Mt. Compass	0.55	0.32	0.27	0.24	0.00
New Zealand Soils‡					
Okaihau gravelly clay loam	4.45	0.55	0.41	0.07	0.02
Te Kopuru sand	0.94	0.04	0.09	0.08	0.07
Outram soil	1.65	0.19	0.11	0.06	0.06
Wehenga silt loam	0.81	0.05	0.13	0.07	0.00
Ngaio silt loam	0.72	0.22	0.18	0.14	0.05

*See text for description of methods.

†Arranged in order of decreasing response to Molybdenum.

‡Order of response not known.

Normal ammonium acetate (Method 6) extracted too little molybdenum to differentiate the soils. This is in line with the weak extracting power of acetate for phosphate mentioned above.

Extraction with alkali (Methods 3 and 4) gave increased amounts of molybdenum. Difficulty was found with these methods in that sodium chloride was precipitated from the acidified extracts on addition of ether. However, recovery of added molybdenum showed that the results were reliable. There is a highly significant positive correlation, $r = 0.78$, between the molybdenum extracted by 2 per cent sodium hydroxide and the loss on ignition of 16 soils examined, suggesting that there is a definite fraction of the soil molybdenum associated with the soil organic matter.

Oxalate soluble molybdenum

Results from the oxalate extraction, alone, agreed reasonably well with the order of response given by Dr. Piper for the Australian soils, and this method has been adopted for determining molybdenum availability in a survey of the molybdenum status of soils.

O. Tamm[15] first used this solution to determine the inorganic non-clay material of soils. It exerts a powerful action on the colloidal layers surrounding the soil mineral particles, but does not appreciably attack the particles themselves. The solution consists

of 24.9 g ammonium oxalate plus 12.605 g oxalic acid per litre, pH 3.3, and has sufficient buffer capacity to prevent any material change in pH when shaken with soil. Twenty-five grams of air-dry soil is shaken overnight with 250 ml of the buffer, and molybdenum is determined in an aliquot of the extract by the modification of Perrin's method.[10]

This extractant has two advantages. First, the purpose was to determine exchangeable molybdate. Secondly, modybdic acid forms very stable complexes with oxalic acid, viz. $MoO_3 . C_2H_2O_4$ and $2MoO_3 . C_2H_2O_4$. The normal analytical reactions of molybdenum are inhibited in the presence of considerable amounts of oxalic acid (see Feigl[16]). As used here, the molybdate absorbed on the soil colloids and clay is presumably replaced by the oxalate ions, the exchange being made irreversible by formation of the strong molybdenum - oxalic-acid complexes, so that a single extraction is as efficient as a leaching. A further effect of the oxalate buffer is the dispersion of the soil particles.

SURVEY OF NEW ZEALAND SOILS

Field Officers of the Department of Agriculture have laid down simple observational topdressing trials on a number of areas where the molybdenum level is low, mainly in Otago and Southland. Certain of these trials were reported by Davies, Holmes and Lynch[17]. There have been a number of very marked responses to applications of 2½ oz per acre of sodium molybdate applied in solution (Table III). The usual form of response is a stimulation of clover growth through increased nitrogen fixation by the nodule organisms[18].

All soils showing responses contain less than 0.14 p.p.m. molybdenum and have a pH of 6.3 or less. Only two slight responses have occurred on soils with a higher pH. Where the pH level is above 6.0 but molybdenum below 0.14 p.p.m, there have been 15 negative trials.

Responses have also occurred to as little as ⅛ oz/acre of sodium molybdate, an amount which would be impossible to detect chemically in a 0-3 in. soil sample. The molybdenum extracted by the oxalate solution must therefore be a potentially available supply which correlates well with field responses at reactions below pH 6.0, although the plants actually need far less. Above this pH, the release of molybdenum must be sufficiently rapid to enable nitrogen fixation to proceed normally, although the analyses may give a low figure.

TABLE III. MOLYBDENUM STATUS OF SOILS FROM OBSERVATIONAL TOPDRESSING TRIALS

Field Responses to Molybdenum	Locality	Soil Analysis	
		pH*	Available Mo (p.p.m.)
Nil	Banks Peninsula	5.3	0.15
pH less than 6.0	" "	5.4	0.15
	Te Oka	5.4	0.17
	Morrinsville	5.6	0.15
	Akaroa	5.7	0.19
	Banks Peninsula	5.9	0.14
			Average: 0.16
pH 6.0 or greater	Pukeuri	6.0	0.11
	"	6.0	0.11
	Upper Hook	6.1	0.11
	Maungatua	6.2	0.04
	Airedale	6.2	0.12
	Waimate	6.3	0.09
	Teschmakers	6.4	0.11
	Airedale	6.4	0.20
	Tapui	6.4	0.10
	Inchholme	6.4	0.14
	Waihao Downs	6.4	0.22
	Milton	6.5	0.03
	Totara	6.5	0.11
	Hina Hina	6.5	0.18
	Ardgowan	6.5	0.15
	Nth. Taieri	6.6	0.13
	Tokaraki	6.6	0.11
	Sth. Hillend	6.7	0.08
	Winton	6.7	0.17
	Maungatua	6.8	0.04
	Berwick	7.2	0.03
			Average: 0.12
Slight	Okiterama	5.3	0.14
	Maungatua	5.4	0.08
	Okaihau	5.7	0.07
	Tokaraki	6.1	0.06
	Wangaloa	6.5	0.11
	Stony Creek	6.8	0.07
			Average: 0.09
Good	Hindon	4.4	0.08
	Sth. Hillend	5.1	0.07
	Herbert	5.2	0.05
	Nth. Taieri	5.2	0.06
	Pahiatua	5.2	0.09
	Berwick	5.4	0.03
	Airedale	5.4	0.08
	Invermay	5.5	0.04
	Maruakoa	5.5	0.13
	Te Hana	5.6	0.07
	Wyllies Crossing	5.6	0.10
	Woodside	5.7	0.04
	Woodside	5.7	0.04
	Kelvin Grove	5.7	0.04
	Five Forks	5.8	0.07
	Whitford	5.9	0.03
	Wyllies Crossing	5.9	0.07
	Henley	5.9	0.07
	Queen's Flat	5.9	0.09
	Outram	5.9	0.12
	Herbert	6.0	0.12
	Woodside	6.1	0.04
	Outram	6.1	0.05
	Herbert	6.3	0.03
			Average: 0.07

* pH determined on a 1:2.5 aqueous soil suspension

In addition to these trials a wide range of soils has been examined for oxalate soluble molybdenum. Some representative figures are given in Table IV. The soils have been arranged in the classification used by the Soil Bureau, Department of Scientific and

TABLE IV. AVAILABLE MOLYBDENUM CONTENT OF SOME NEW ZEALAND SOIL GROUPS

Locality	Number of samples with Mo. Level (p.p.m.) from:				
	0.00-0.05	0.06-0.10	0.11-0.15	0.16-0.20	Over 0.20
SOUTH ISLAND					
Taieri Area					
Transitional yellow-grey to yellow-brown earths	23	10	2	1	2
Yellow-brown earths	1	3	1	1	-
Recent soils from alluvium	-	-	-	-	7
North Otago Area					
Yellow-grey earths	4	9	8	3	1
Rendzinas	-	-	1	-	2
Canterbury Area					
Yellow-grey earths	2	18	5	2	-
Transitional yellow-grey to yellow-brown earths	-	5	2	-	-
Yellow-brown earths	1	-	1	2	-
Yellow-brown sands	-	1	-	-	-
Gley soils	-	1	-	-	-
Organic soils	-	-	-	-	2
Recent soils from alluvium	-	1	1	-	-
Blenheim Area					
Yellow-grey earths	-	-	-	3	-
Transitional yellow-grey to yellow-brown earths	-	-	-	2	2
Yellow-brown earths	-	-	1	1	-
Recent soils from alluvium	-	-	1	-	2
NORTH ISLAND					
Wellington Area					
Yellow-grey earths	2	2	1	-	-
Yellow-brown earths	-	-	4	1	3
Yellow-brown sands	2	-	-	-	-
Yellow-brown loams	-	-	1	-	3
Gley soils	1	-	-	-	-
Organic soils	-	1	-	-	-
Recent soils from alluvium	-	-	1	-	-
Hawkes Bay-Gisborne Area					
Yellow-grey earths	-	2	1	-	1
Yellow-brown loams	-	2	-	1	1
Recent soils from alluvium	-	-	-	-	3
Taranaki Area					
Yellow-brown earths	-	-	1	1	-
Yellow-brown loams	-	-	1	1	13
Gley soils	-	-	-	-	1
Recent soils from alluvium	-	-	-	-	1
South Auckland Area					
Yellow-brown earths	1	1	2	2	1
Yellow-brown pumice soils	-	-	2	2	-
Yellow-brown loams	-	-	1	3	3
Brown granular clays	-	-	-	-	7
Gley soils	-	-	-	-	1
Organic soils	2	-	-	-	2
Recent soils from alluvium	1	1	1	1	2
North Auckland Area					
Brown-grey earths	-	-	1	-	-
Yellow-brown earths	6	18	7	5	3
Yellow-brown sands	4	3	1	-	-
Yellow-brown loams	-	1	-	-	-
Brown granular clays	1	2	2	-	-
Red and brown loams	2	1	-	-	-
Rendzinas	-	1	-	2	-
Gley soils	-	1	1	-	-

Industrial Research. Large areas of soils derived from loess in the tussock and browntop areas of Otago (classified as yellow-grey earths and transitional yellow-grey - yellow-brown earths) are low in molybdenum, and topdressing with small amounts of this element may be the means of greatly increased pasture production in these areas.

The Influence of Soil Reaction on the Availability of Molybdenum

Piper and Backwith[19] showed that the molybdenum uptake by three plant species from two soils at varying reactions, became much greater above pH 7 - 7.5, and also that the average molybdenum content of *Trifolium subterraneum* from 17 areas in the Adelaide Hills in South Australia, where soil pH varied from 5.17 to 6.33, was 0.10 p.p.m., while from 15 areas in the South East, it was 0.77 p.p.m. with a pH range of 5.66 to 8.63. Moore[20] also found an increase in molybdenum content correlated with increasing alkalinity in three plant species grown on several soil types. Cases of whiptail in cauliflowers have been cured by application of lime[21]. There is thus good evidence that plant uptake is greater with more alkaline conditions, indicating increased availability of molybdate ions.

This effect of small increases in available molybdenum with increasing pH level is demonstrated in a topdressing trial on pasture at the Invermay Agricultural Research Station[17]. The trial was laid down on 8 December, 1950, and by 11 January, 1951, striking growth differences were noted. Yield cuts were made on that date and also on 13 February and 28 March. In all cuts the molybdenum treatments gave a significant increase in yields, as also did 3 tons of ground limestone without any added molybdenum. Lower levels of liming were not effective. Soil samples were taken from some of the individual treatments in September and November 1951 and have been analysed for available molybdenum. The data are given in Table V.

Table V. Molybdenum Lime Trial at Invermay Research Station: Variation of Molybdenum levels and pH with depth

Treatment	Yield (Total of 3 cuts wet wt.) lb/acre	Mo (in p.p.m.) insample at depth (in.) indicated: 0-½	½-1	1-1½	1½-2	2-2½	2½-3
2. Control	10,200	0.03	0.03	0.04	0.03	0.03	0.04
4. Limestone, 3 tons	15,000	0.07	0.05	0.05	0.04	0.04	0.03
5. Sodium molybdate, 2½ oz	15,500	0.15	0.13	0.07	0.03	0.04	0.04
8. Limestone, 3 tons + sod. molybdate, 2½ oz	15,400	0.14	0.12	0.04	0.04	0.05	0.03
				pH			
2. Control		5.5	5.4	5.6	5.4	5.4	5.4
4. Limestone, 3 tons		6.9	6.7	6.4	6.5	6.2	5.9
5. Sodium molybdate, 2½ oz		6.1	5.7	5.7	5.8	5.8	5.8
8. Limestone, 3 tons + sod. molybdate, 2½ oz		7.3	6.7	6.2	6.2	6.1	5.5

It can be seen that the treatments have affected only the top 1½ in. of soil. There is a large increase in available molybdenum where 2½ oz of sodium molybdate was applied and a smaller increase in the lime-only plot. This increase, brought about by 3 tons of limestone has caused an increase in yield of approximately 50 per cent. However, limestone has made no significant difference to the yield in the molybdenum-treated plots. Limestone at 3 tons/acre has apparently accelerated the release of sufficient molybdenum for the requirements of the clover nodule organism and applications of sodium molybdate have not had any further effect.

The increase in available molybdenum over the control, calculated by taking the weight of an acre to ½ in. depth as 125,000 lb, shows that 3 tons of limestone has made available the equivalent of 0.35 oz of sodium molybate. Of the 2½ oz of sodium molybdate applied to Plots 5 and 8, approximately half has been recovered in an available form as shown by oxalate solubility.

WHIPTAIL DISEASE IN CAULIFLOWERS

A number of soils collected by Field Officers of the Horticulture Division, Department of Agriculture, from areas where cauliflowers showed distinct symptoms of whiptail and from some healthy areas have been analysed for available molybdenum.

The oxalate extraction method did not differentiate between healthy and affected soils and it was thought that other factors than molybdenum supply might be having an influence. It has been reported[22] that there is a similarity in the field symptoms of molybdenum deficiency and manganese toxicity, and so the possibility of the latter as a conflicting factor is being studied.

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References

1. Anderson, A. J., 1942: *J. Aust. Inst. Agric. Sci. 8*: 73-75.
2. ————, 1946: *J. Coun. Sci. Ind. Res. Aust. 19*: 1-15.
3. Stephens, C. G. and Oertel, A. C., 1943. *Ibid. 16*: 69-73.
4. Fricke, E. F., 1943: *Tasmanian J. Agric. 14*: 69-73.
5. ————, 1945: *Ibid. 16*: 1-4.
6. ————, 1945: *Ibid. 16*: 109-11.
7. Mitchell, R. L., 1948: *Comm. Bur. Soil Sci. Tech. Comm. No. 44.*
8. Mulder, E. G., 1948: *Plant and Soil, 1*: 94-119.
9. Nicholas, D. J. D. and Fielding, A. H., 1950: *Nature, 166*: 342-3.
10. Perrin, D. D., 1947: *N.Z. J. Sci. Tech, A28*: 183-7.
11. Dick, A. T. and Bingley, J. B., 1947: *Aust. J. Exp. Biol. & Med. Sci. 25*: 193-202.
12. Kurtz, T., De Turk, E. E. and Bray, R. H., 1946: *Soil Sci. 61*: 111-24.
13. Low, P. F. and Black, C. A., 1950: *Ibid. 70*: 273-90.
14. Lynch, P. B., Davies, E. B. and McNaught, K. J., 1951: *Proc. Brit. Comm. Off. Conf., Spec. Conf. in Agric. Aust.*, 1949: pp. 169-78.
15. Tamm, O., 1922: *Medd. fr. Statens Skogsforsoksanstalt, 19*: 387-404. (See Monthly Letter No. 1, Imp. Bur. Soil Sci.)
16. Feigl, F., 1940: "Specific and Special Reactions" p. 50, Elsevier.
17. Davies, E. B., Holmes, G. A. and Lynch, P. B., 1951: *N.Z.J. Agric. 83*: 247-50.
18. Anderson, A. J. and Thomas, M. P., 1947: *Coun. Sci. Ind. Res. Aust. Bull.* 198.
19. Piper, C. S. and Beckwith, R. S., 1951: *Proc. Brit. Comm. Off. Conf., Spec. Conf. in Agric., Aust.* 1949: pp. 144-55.
20. Moore, C. W. E., 1950: *Aust. J. Agric. Res. 1*: 43-51.
21. Plant, W., 1950: *J. Min. Agric. 57*: 130-4.
22. Hewitt, E. J., Jones, E. W. and Nicholas, D. J. D., 1948: *Ann. Rep. Long Ashton Res. Sta.* 1947. pp. 70-81.

COMPOSITION OF THE SOIL-ORGANIC-MATTER COMPLEX IN PUMICE SOILS OF THE TAUPO ASH SHOWER

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Summary

The need for investigating the organic matter composition of pumice soils is discussed and areas of soil, all derived from the Taupo ash shower, at various stages of development, which have been examined, are described.

The analytical results given show that:

(1) There is a rapid accumulation of organic matter in the pumice soils under grass-land farming;

(2) This organic matter does not decompose very rapidly;

(3) The rate of decomposition of cellulose is much slower than in clay mineral soils;

(4) The distribution of the humic acids shows that, in spite of good aeration, the oxidation process by which they are formed is much slower than in clay mineral soils;

(5) The nitrogen analyses show that the nitrogen-containing compounds are easily soluble and not closely bound to the humic compounds.

It appears that the decomposition processes occurring in the pumice soils are either not the sam, or do not take place at the same rate as in the clay mineral soils. It is suggested that the non use of lime in farming practice, by restricting bacterial activity and particularly earthworm activity, may be the explanation.

Introduction

The Taupo ash shower covers a considerable area in the centre of the North Island. Much of the land is now being developed but presents problems due to the low natural fertility. Consequently, a concentrated attempt is being made to study the fertility of these soils, and work on the phosphorus status and biological activity has been in progress for some time at this Station.

It had been observed that the organic matter appeared to build up to an unusual degree in these soils and that it was of unusual composition. A quantitative and qualitative study appeared warranted since fertility depends partially on the characteristics of the soil organic matter. The object was to determine the changes in the nature and quantity of the organic matter as a result of increasing periods of time under pasture.

Experimental Procedure

Description of the Region Examined

The soils examined, which were obtained from the Ngakuru-Waikiti Valley area, are all derived from the comparatively recent Taupo ash shower. Consequently, the material below the top few inches is largely unchanged pumice, weathering has not reached an advanced stage and the soil is low in clay minerals.

In developed areas, as a result of ploughing a concentration of organic matter is commonly found in the 3-6-in. layer.

Sampling Sites

These were selected to cover the various stages of development from virgin pumice to old, high producing pastures, and are listed below:

(1) *Virgin pumice, lowland country.* A small area of Taupo Sandy Silt,* deep subsoil phase, on the rolling country near Ngakuru. The vegetation consisted of browntop and manuka.

(2) *Virgin pumice, hill country.* An area of Waipahi sandy silt at an altitude of 1,500 ft on the Waikite development block. The vegetation was typical tussock and heath.

(3) *High producing perennial rye grass (Lolium perenne) pasture.* Areas of 1-year-old and 12-year-old pastures on the Waikite development block, and of a 20-year-old pasture near Ngakuru, all on Taupo Sandy Silt deep subsoil phase.

(4) *Poor producing pasture.* An area of 10-15-year-old pasture, near Ngakuru, poor in perennial rye grass and clovers. The soil type is Whenuaroa Sandy Silt.

(5) *Pumice soil under lucerne.* A vigorous 4-year-old lucerne stand on Taupo sandy silt near Ngakuru was chosen and sampled. This type of area was included to cover the case where fairly high amounts of nitrogen would be expected to be available to the soil bacteria.

Sampling and Preparation of Samples

Samples were taken from the 0-3-in., 3-6-in. and 6-9-in. layers.

Large bulk samples were collected for each depth. These bulk samples consisted of a number of small samples taken with a spade. These were mixed and then quartered down to give 250-400g samples which were air-dried and ground to pass a 1-mm sieve.

Fractionation of the Organic Matter

The modified scheme of proximate analyses described in a previous paper[1] was used. This divides the organic matter into the following fractions: Waxes, etc., soluble in organic solvents; hemicellulose; cellulose; humic acid soluble in sodium carbonate solution; humic acid soluble in sodium hydroxide solution; and ligno-humin. Total-nitrogen analyses by the micro-Kjeldahl method[2] were done on the original soil samples and on the acid extracts obtained in hydrolysing the hemicellulose and cellulose. Ash content was determined by igniting the oven-dry samples in a muffle at 500° c for six hours.

Results of Analyses

The results of the proximate analyses are listed in Table I and include, for comparison, figures obtained from clay mineral soils. For comparative purposes, the results have been converted to a percentage of the loss on ignition, in order to eliminate the effects due to differing ash contents.

The fractions determined account for 60-75 per cent of the material lost on ignition. This discrepancy is to be expected, because ignition removes both organic matter and water not removed at 110° c. Further, the protein fraction has not been included and a number of minor organic constituents have not been determined. In the case of mineral soils which contain a higher proportion of clay minerals, a lower fraction of the loss on ignition is accounted for by the organic fractions.

DISCUSSION OF RESULTS

Since comparisons of the loss-on-ignition figures give an indication of the variations in total organic matter, the differences between these figures for the virgin and developed soils give an estimate of the rate of build up of the soil organic matter. It should be noted that, where the virgin top 0-3-in. layer has been ploughed under, this rate of build-up of organic matter will be shown by the difference between the loss on ignition figures for the new pasture topsoil and the 3-6-in. layer of the virgin soil. The following conclusions may be drawn:—

The 0-3-in. layer of the virgin pumice has a loss on ignition of from 14 to 17 per cent, which drops to the much lower level of 6-9 per cent in the 3-6-in. layer. The figures for the one-year-old pasture, 0-3-in., 9 per cent, and 3-6-in. 13.6 per cent, show how the richer surface layer has been ploughed under and replaced by a poorer layer of soil.

Under the ten- and twenty-year-old pastures, the loss-on-ignition figures of 17-20 per cent show the marked accumulation of organic matter which has occurred. This probably represents a build-up from the original 9 per cent of the virgin 3-6-in. layer which would be turned up in the initial ploughing. Under lucerne, the high loss-on-ignition figure of 19 per cent extends down to the 3-6-in. layer.

The clay mineral soils in general have a lower loss on ignition of which a smaller proportion is organic matter. As the samples of both clay mineral and pumice soils were taken from under good perennial rye-grass/white-clover pasture, the results indicate that the rate of decomposition of added plant material is slower in the pumice soils.

Samples of the buried topsoil, described previously, had loss-on-ignition figures of 13 per cent (Sample No. 10). Comparison of this figure with that of a virgin pumice, viz. 14-17 per cent, shows that there has been little decomposition of this buried organic matter, even after, in one case, twenty years.

Comparisons of the distribution of the individual fractions of the organic matter should give indications of the decomposition processes which are operating under these particular conditions of soil type and farming. The results obtained may be summarised as follows:—

(1) *Waxes, Resins, etc.* No marked variations occur in the amount of this fraction.

(2) *Carbohydrates.* In all cases the amount of hemicellulose is greater than the cellulose, which was to be expected as cellulose is more rapidly decomposed by soil bacteria.[3] However, in comparison with the mineral soils the surface layers of the pumice soils contain higher amounts of cellulose, with the single exception of the recently ploughed one year pasture soil. In the lower 3-6 in. layers, the cellulose figures are generally nearer to those of the mineral soils, although the total carbohydrate is still high. The results suggest that, in the surface

layers, bacterial decomposition is sufficiently slow to permit the accumulation of cellulose.

(3) Humic Acids. It has been postulated by Forsyth[4] that the conversion of lignin to humic acids is an oxidation process in which the lignin methoxyl groups are converted first to phenolic hydroxyl groups and then to carboxyl groups. On this basis a scheme of fractionation of the humic acids described in detail in a previous paper[1] has been developed. The scheme depends on the fact that the initial humic acid containing only hydroxyl groups will be soluble in sodium hydroxide solution, whereas the more oxidized humic acid containing carboxyl groups will be soluble in sodium carbonate solution as well. It was confirmed[1] that with increasing decomposition in the peats there was a progressive increase in the proportion of carbonate-soluble humic acid. In clay mineral soils, in which the organic matter is highly decomposed, the humic acid is practically all carbonate soluble. Evidence was also produced to show that the oxidation process was largely independent of bacterial activity.

Estimation of the two humic fractions will therefore give an indication of the degree of decomposition of the lignin and of the rate of decomposition. Because of their good aeration, the pumice soils would be expected to be similar to the mineral soils with a dominantly carbonate-soluble humic fraction; however, this is not entirely so.

In the surface layers of soil under pastures (Samples 5, 7, 9 and 12), the ratio of carbonate-soluble to hydroxide-soluble humic acid is never greater than 2:1 compared with ratios ranging from 4:1 to 9:1 in the mineral soils. In the deeper layer from these areas, only Sample 13 from under poor pasture has a ratio greater than 2:1.

The virgin pumice soils, with their slower rate of addition of plant material, tend to have more carbonate-soluble humic acid in the 0-3-in. surface layer, but not in the 3-6-in. layer in which the amount of the two fractions is almost equal.

The ratio of the two humic acids of less than 2:1 in samples of the buried topsoil, e.g., No. 10, shows that the oxidation process has not proceeded very rapidly after burial.

These results show that the process of oxidation of the lignin is slower in the pumice soils,

(4) *Ligno-Humin*: The amount of this complex present is also a measure of the rate of conversion of plant lignin to the soluble humic compounds, etc. In all cases the amount of this fraction is greater than in the clay mineral soils, suggesting a slower rate of oxidation.

Presumably the ligno-humin/humic-acid complex is not inert and in normal soil conditions it must be gradually destroyed, otherwise over a period of years a peatlike material would be formed by accumulation. If the actual percentages in the soils of ligno-humin plus humic acids are compared, it can be seen that, whereas the clay mineral soils contain 3-4 per cent of the complex, the surface samples of the pumice soils, both virgin and pasture, contain from 6 to 8 per cent. The surface layer from under lucerne contains the remarkably high amount of 11 per cent. These results show that in the pumice soils the ligno-humin/humic acid complex is not so readily decomposed and tends to accumulate.

Nitrogen Status

Total nitrogen was determined in the soils and in the hydrochloric (2 per cent w/w) and sulphuric acid (7 per cent w/w) hydrolysates

obtained in determining the hemicellulose and cellulose fractions. The sample numbers quoted are those of Table 1.

TABLE 1. COMPOSITION OF THE ORGANIC MATTER OF PUMICE SOILS
(Expressed as a percentage of the loss on ignition)

Description of Sample	No.	Waxes, Resins, etc.	Carbohydrate		Humic Acids		Lignohumin	Loss on ignition (%)
			Hemicellulose	Cellulose	Carbonate soluble	Hydroxide soluble		
Virgin, lowland								
0-3 in.	1	3.3	14.7	7.4	9.0	5.0	25.5	17.0
3-6 in.	2	3.4	7.7	5.4	13.0	10.0	39.0	6.1
Virgin, hill country								
0-3 in.	3	4.3	11.1	7.0	14.6	3.4	25.0	14.4
3-6 in.	4	4.6	1.0	1.4	9.7	9.9	29.1	9.9
Good pasture, 1 year								
0-3 in.	5	3.7	11.6	1.0	10.8	5.3	38.0	9.2
3-6 in.	6	4.6	16.1	5.0	17.0	8.2	30.0	13.6
Good pasture, 10 years								
0-3 in.	7	3.9	8.6	3.7	10.9	7.0	31.6	17.4
3-6 in.	8	3.5	10.4	3.9	10.9	11.6	27.8	11.5
Good pasture, 20 years								
0-3 in.	9	3.5	14.3	5.6	6.3	3.1	24.0	20.3
3-6 in.	10	2.6	5.2	3.2	10.2	7.8	27.0	13.7
6-9 in.	11	3.7	11.4	2.3	15.4	6.4	29.0	8.2
Poor pasture, 10-12 years								
0-3 in.	12	3.8	11.8	5.7	9.6	7.8	23.1	17.7
3-6 in.	13	3.1	7.8	3.3	18.3	5.0	25.8	12.0
Lucerne, 4 years								
0-3 in.	14	2.5	11.2	6.6	18.0	8.4	31.6	19.0
3-6 in.	15	2.6	5.2	1.7	16.0	4.2	31.1	18.0
Clay Mineral Soils								
Hamilton Clay Loam								
0-4 in.	16	2.6	7.5	1.6	9.2	0.8	14.1	12.0
Horotiu Sandy Loam								
0-4 in.	17	2.6	7.5	2.1	11.4	2.9	9.2	18.3
Manawatu Silt Loam								
0-4 in.	18	5.1	16.3	5.9	8.4	2.7	17.3	11.0

In the 0-3-in. surface layer total nitrogen figures of 0.46 per cent (No. 1), 0.6 per cent (Nos. 7 and 14) and 0.78 per cent (No. 9), were obtained, whilst in the 3-6-in. layer the figures are much lower; e.g., 0.11 per cent (No. 2) and 0.2 per cent (No. 11). On the basis of numerous total nitrogen analyses, done by the soil section of this laboratory, the figures obtained for the 0-3-in. layer would be classed as high. The soils from under the older high producing pastures or lucerne are highest in total nitrogen. In the case of the lucerne soil, even the 3-6-in. layer is comparatively high, viz. 0.53 per cent (No. 15).

Although the conditions of acid hydrolyses used are empirical, the amount of nitrogen dissolved does give an indication of the chemical stability of the nitrogen containing compounds. In all cases, 70-90 per cent of the nitrogen is dissolved, and generally two-thirds of this percentage by the weaker hydrochloric acid. These results may be compared with those for peats[1] in which only 40-50 per cent of the total nitrogen is dissolved. They indicate that the nitrogen in the pumice soils is mainly present as easily hydrolysed protein compounds and has not been rendered insoluble by conjugation or combination with the humic fraction.

Conclusions

The results presented show that even under the conditions of high producing pasture the rate of decomposition of added organic matter is slow, and that there is a progressive build up in organic matter while the fractionation results suggest that the decomposition process is akin to that occurring under anaerobic conditions. These results are unexpected in view of the good aeration of pumice soils, the apparent satisfactory nitrogen position, high reported bacterial activity and the adequate phosphate and potash supplied under good farming management.

However, an explanation may lie in the fact that liming is not practised in pumice farming because of the lack of visible plant response. Lime may be necessary to aid the process of bacterial decomposition. It has also been suggested that lack of lime limits the activity of earthworms in the pumice, and it is well known that earthworms are a major factor in decomposing the organic matter added to the soil.

The results presented have given an indication of the rate of decomposition of the organic matter in the pumice soils and of the composition of the organic matter. From these results, conclusions, which may be of practical value in the agricultural development of the pumice soils, have been obtained.

Discussion

The author wishes to thank Dr. R. H. Jackman for help in the selection of sampling sites and in the preparation of this paper, and Mr. R. E. R. Grimmett for granting permission to publish this paper.

References

1. Bailey, R. W., 1953: The composition of the organic fraction of Waikato and Hauraki Peats. *N.Z. J. Sci. Tech. A34*: 421-9.
2. White, E. P., Thompson, F. B. and Brice, N., 1948: Application of Dumas Micro-method to Pasture Nitrogen Analysis. *Analyst, 73*: 146-8.
3. Waksman, S. A., 1938: "Humus." Williams and Wilkins, Baltimore, pp. 160-9.
4. Forsythe, W. G. C., 1947: The Characterisation of Humic Complexes of Soil Organic Matter. *J. Agric. Sci. 37*: 132-8.

COMPOSITION OF THE ORGANIC FRACTION OF THE WAIKATO AND HAURAKI PEATS

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Summary

A description of the stages of decomposition of areas of peat in the Waikato and Hauraki regions is given.

On the basis of recent work on the humic compounds of soil organic matter the modified scheme of fractionation described has been developed.

The formation of a hydroxide-soluble and then a carbonate-soluble humic acid is suggested and that with increasing decomposition the proportion of carbonate-soluble humic acid will increase.

Results obtained in the fractionation of the different peats are given and discussed. They show that:—

(1) With increasing decomposition the carbohydrate content falls off rapidly, cellulose being decomposed more readily than hemicellulose.

(2) The humic acid relationship found supports the suggested theory. The raw peats contain humic acid which is largely hydroxide soluble. Continuing decomposition increases the proportion of carbonate-soluble humic acid until in the most decomposed peats and mineral soils it is the major form.

Analyses of samples from various depths in the peat suggest that:

(1) The decomposition of carbohydrate is a bacteriological process confined to the surface layers.

(2) The formation of humic acids continues even at great depth and is probably a chemical process.

It is concluded that under suitable conditions the raw peats are more likely to decompose satisfactorily than are the already partly decomposed peats. From the point of view of availability to bacteria of the different carbon compounds present, the organic matter of the raw peats is more like that in a mineral soil than is the organic matter of the more decomposed peats.

Introduction

A major project of the Rukuhia Soil Research Station has been a study of the means of developing the extensive areas of peat in the Waikato and Hauraki areas. A description of this work, including details of the location and extent of the peat areas, the major mineral deficiencies, and the various practical aspects of development has been given by Thompson and Elliott[1, 2, 3]. The present paper reports the results of a brief survey of the distribution of the major organic fractions of these peats. Apart from supplying fundamental data on the composition of the peats themselves, the results should be of interest as they cover five stages of development ranging from young growing peat to old decomposed peat, all of which have apparently developed under similar conditions.

The five areas sampled in this work are in order of degree of decomposition:

(a) *Moanatuatua swamp.* The area sampled consists of very raw light brown fibrous peat, and the surface is still actively growing.

(b) *Hauraki swamp.* The undeveloped areas of this swamp consist of very raw fibrous peat. Samples of this raw peat were taken from an experimental area near Kerepehi.[2]

(c) *Rukuhia swamp.* The experimental area[2] on this peat consists of darker and less fibrous material than the two raw peats described, and appears to be more decomposed.

(d) *Hauraki swamp,* developed peat. Certain areas of the Hauraki peat have been farmed for a number of years and the surface peat has changed to a dark granular material. Samples of this material taken at Waitakaruru[4] provide an example of the peat described in (b) after induced decomposition.

In the swamps so far described, the peat is up to 30 ft deep.

(e) *Ruakura swamp.* The experimental area on this swamp[2] is shallow peat 2–3 ft deep, which has not only ceased growing, but has been actively farmed for a number of years. It consists of dark granular material, and represents the most advanced stage of decomposition of the five areas.

For comparison analyses of two mineral soils from adjacent areas in the Waikato district have been included.

Method of Fractionation

The method most widely used for fractionating soil or peat organic matter is Waksman's scheme of proximate analysis[5], or a modification of it. This scheme divides the organic matter into the following fractions: solvent soluble, i.e., waxes, resins and their soluble constituents; hemicellulose; cellulose; protein; and ligno-protein. Although this system has been developed from an appreciation of the derivation of soil organic matter from plant material it is an oversimplification of the position. This is particularly so for the fraction called ligno-protein which besides including any unchanged plant lignin, contains the various humic and humin fractions isolated by previous workers. As this fraction makes up the greater portion of the peat it was considered necessary to develop a fractionation scheme which would define more accurately its components.

Recent work of Forsythe[7] has clarified the position by showing that when the humic acid fraction, i.e. the fraction soluble in weak sodium hydroxide and precipated by strong acid, was hydrolysed with 2 per cent hydrochloric acid the co-precipitated compounds were removed to leave a humic fraction of fairly definite composition. They postulated the hypothesis that this humic acid is formed from lignin by the progressive oxidation of the methoxyl groups to phenolic hydroxyl groups, and then to carboxyl groups. At the same time quinone groups are formed. Using this hypothesis, a scheme for fractionating the humic-lignin complex can be developed along the following lines:

As the organic matter decomposes, the humic acids first produced will be rich in phenolic hydroxyl groups. However, with continuing decomposition, these hydroxyl groups will be oxidized to carboxyl groups until finally a humic acid rich in carboxyl groups

will be formed. A phenolic hydroxyl group is too weak an acid to replace a carbonate ion, whereas a carboxyl group will do so. This means that although a carboxyl-rich humic acid will be soluble in both sodium carbonate and sodium hydroxide solutions, a hydroxyl-rich humic acid will be soluble in the sodium hydroxide only.

It should therefore be possible to fractionate the soluble humic acids into carbonate and hydroxide-soluble fractions. The insoluble material will presumably consist of unchanged lignin together with substances intermediate in composition between lignin and hydroxide soluble humic acid. It is, therefore, called ligno-humin.

With increasing decomposition and age of the peat, there should be a progressive increase in the amount of carbonate-soluble humic acid and a decrease in the amount of hydroxide-soluble humic acid. If these deductions are sound, determination of the two humic fractions should give an indication of the amount of decomposition which has taken place.

The scheme of proximate analyses used in this work has therefore been modified to determine the following fractions: waxes, resins, etc.; hemicellulose; cellulose; carbonate-soluble humic acid; hydroxide-soluble humic acid; protein; and ligno-humin.

EXPERIMENTAL PROCEDURE

Methods of Sampling and Preparation of Samples

Bulk samples of 2–3 lb were taken with a spade at the required depth, and from an area of several hundred square feet. After air drying at 40°c., the material was coarsely ground, quartered down to 200–400 g and the final sample ground to 40–50 mesh. With the fibrous peats, grinding in a C. and N. Junior Mill was preferred. All analyses were performed on the air-dried material and corrected for moisture as determined by loss at 110°c.

To study the variations in composition with increase in depth, a series of samples were taken down the profile of the swamp. The sampler described by Harris and Filmer[4] was used to obtain these samples. For each depth a number of samples were taken over an area of 50–100 sq ft and bulked into one sample for fractional analyses. Samples were taken at intervals of 3–5 ft down the profile to a depth of 23 ft.

Scheme of Proximate Analyses

Two 10-g samples of the peat were successively extracted with ether, acetone, and 1 : 2 alcohol: benzene. The soluble fractions were determined by evaporating off the solvents and weighing the residues. An extraction time of 10–12 hr was required for each solvent. The hemicellulose was then determined by boiling 5 g of the extracted peat with 250 ml of 2 per cent (w/w) hydrochloric acid for 5 hr and measuring the reducing sugars in the filtrate. The Shaffer-Somogyi[8] micro method of reducing sugar analyses was used in conjunction with Doak's[9] method of deproteinizing with cadmium-sulphate/sodium-hydroxide. It was found that deproteinizing gave lower but much more consistent results

The residue remaining after the hydrochloric-acid hydrolyses was divided into two equal portions. To one fraction, 10 ml of 72 per cent sulphuric acid was added, and, after standing for two hours, the mixture was diluted with 150 ml of water and refluxed for five hours.[5] Reducing sugars determined in the filtrate were reported as cellulose.

The second fraction was extracted first with 100-ml portions of 2 per cent sodium carbonate solution until almost colourless extracts were obtained. Generally 4-5 extractions were sufficient. The extraction process was then repeated with 2 per cent sodium hydroxide solution. The individual extractions were carried out by shaking for two hours on a wrist action shaker and then centrifuging the mixtures. After filtering the extracts, the humic acids were precipitated with excess hydrochloric acid, allowed to settle, filtered, washed, dried and weighed. It was shown that the preliminary hydrolyses used to determine the hemicellulose fraction had removed the compounds which would have been co-extracted and precipitated with the humic acids.

The residue remaining from the alkali extraction was hydrolysed with sulphuric acid to remove cellulose, dried, and the loss on ignition determined. As all major fractions except the insoluble ligno-humin complex had been removed, this loss on ignition was reported as ligno-humin.

Total nitrogen analyses, by the micro-Kjeldahl method[10] were done on the original peats and on the acid hydrolysates obtained in the hemicellulose and cellulose determinations. The total acid-soluble nitrogen, multiplied by 6.25, was reported as soluble protein. The insoluble nitrogen is presumably combined with the humic acids and ligno-humin and included in these fractions.

The ash contents of the peats were determined by ignition in the usual manner.

As only certain definite fractions are measured in this scheme it is not to be expected that the results would account for one hundred per cent of the organic matter present. For example, no attempt has been made to define or determine the highly coloured compounds dissolved in the acid hydrolyses.

Results of Analyses

Variations in Composition between the Various Peats

The results of the analyses of the organic matter in the different peats are listed in Table 1. They are reported as a percentage of the ash-free material. In column No. 8 the actual ash contents of the peats are listed for comparison. In each case a number of samples have been analysed and a mean result typical for each area is reported. In general, samples of peat from any particular area gave closely similar fractional analyses.

From the results given in Table 1 it is possible to assess the changes in organic matter composition which have taken place. They may be summarised as follows:—

(1) *Waxes, Resins, etc.*: The percentage of these compounds increases with increasing decomposition, probably because they represent the accumulation of inert plant waxes, etc.

(2) *Carbohydrates*: It is well established that cellulose is more readily decomposed than hemicellulose[7] and this is clearly shown by the figures in columns 2 and 3 of Table I. The cellulose appears to decompose rapidly until a constant figure of about 2 per cent is reached, as shown in Samples 5-13. However, the rate of decomposition of the

hemicellulose is much slower and it is only in the most decomposed of the peats, Nos. 11, 12 and 13, that it approaches the cellulose content. It is to be noted that in the mineral soils the hemicellulose to cellulose ratio is higher than in any of the peats. This is probably due to the higher rates of formation and decomposition of organic matter in mineral soils, and to the greater accumulation of carbohydrates of bacterial origin which would be included in the hemicellulose fraction.

(3) *Humic Fractions*: The postulate that with increasing decomposition the carbonate-soluble humic fraction should increase in relation to the hydroxide-soluble fraction has been strikingly confirmed. In the undecomposed peats, Samples 1-4, the humic fraction is largely hydroxide soluble. As the peats become more decomposed, Samples 5-9, the amount of carbonate-soluble humic acid increases until in the very decomposed samples, 10-13, and the mineral soils, it is the major humic fraction. A detailed study of the hydroxyl and carboxyl contents of these humic fractions is being undertaken.

(4) *Ligno-Humin*: As would be expected, the raw peats are richer in this fraction. It is probable that in these raw peats the ligno-humin more closely resembles true plant lignin than in the older decomposed peats. The decrease in lignin by conversion to humic substances is no doubt partly offset by the overall decrease in organic matter.

(5) *Soluble Nitrogenous Fraction*: There does not appear to be any definite trend in the amount of this fraction.

Variations in Composition with Increasing Depth of the Swamp

As has been explained previously, a series of samples was taken down the profile in the deep swamps. The results for the Moanatuatua and Rukuhia swamps are listed in Table II; those obtained from the Hauraki peat have been omitted as they are very similar to the Moanatuatua results.

In the Moanatuatua series, the total carbohydrate figure which is high in the surface and 3-ft levels changes to a fairly constant low value below the 8-ft level. In the surface samples, the humic acid concentrations are typical for undecomposed peat, i.e. dominantly hydroxide soluble. With increasing depth, there is an increase in the proportion of carbonate-soluble humic acid, suggesting that the oxidation process continues even at great depth. This is also shown by the total amount of humic acid present.

There are two possible explanations of these results. Firstly, the deeper peat accumulated more slowly, thus allowing greater decomposition to take place before it was buried. Secondly, the destruction of the carbohydrate is a rapid bacterial process and the oxidation of the lignin to humic acid a slower chemical process. This second explanation is supported by the fact that bacterial activity is largely limited to the surface layers, whereas a chemical oxidation might not be so limited.

The results from the Rukuhia swamp are similar, although the more decomposed nature of the surface layers suggests that the swamp is older or has ceased growing for some time. It can be seen that the carbohydrate composition, even in the surface layers, has reached a static level similar to the Moanatuatua figures. The humic acid position is also similar, except for the surface layer in which the carbonate-soluble fraction is dominant. It appears that

although there has been a steady slow production of humic acids in the deeper layers there has been a more rapid oxidation of the hydroxide-soluble humic acid to carbonate-soluble acid in the aerated surface layer.

TABLE I. COMPOSITION OF ORGANIC MATTER OF WAIKATO AND HAURAKI PEATS
(Expressed as percentage of ash-free material)

Sample	Origin	Depth (in.)	Description	1	2	3	4	5	6	7	8
					Carbohydrate		Humic fraction				
				Waxes, Resins, etc.	Hemi-cellulose	Cellulose	Carbonate Soluble	Hyrdoxide Soluble	Ligno—Humin	Soluble N as Protein	Ash (%)
1	Moana-tuatua	0-6	Light brown fibrous	6.2	20.7	8.5	2.4	9.0	31.2	—	3.1
2	"	36	"	10.0	13.3	6.4	3.6	15.4	24.6	—	3.1
3	Hauraki Raw	0-6	"	5.7	15.7	7.0	4.6	19.2	36.5	4.5	3.7
4	"	36	"	11.1	7.0	6.0	4.5	16.8	27.6	—	9.1
5	Rukuhia	0-1	Dark brown	8.0	7.3	2.0	16.0	13.0	16.6	4.7	17.8
6	"	0-2	"	9.0	6.2	2.0	14.7	11.4	14.8	6.1	32.0
7	"	4-6	"	10.5	6.0	1.6	16.7	12.9	24.0	—	24.8
8	"	36	"	12.3	5.7	2.6	8.0	21.6	17.0	3.1	9.0
9	Hauraki Developed	0-6	Black granular	6.9	7.4	2.2	13.6	19.6	15.3	7.6	28.1
10	Ruakura	0-2	"	11.2	7.6	3.0	21.3	3.6	29.9	9.8	51.2
11	"	2-4	"	11.6	4.0	2.1	33.3	1.8	22.2	—	50.2
12	"	0-12	"	10.6	3.5	1.6	34.0	6.1	16.2	3.9	31.6
13	"	12-24	"	10.7	4.2	3.8	29.3	6.0	14.4	4.0	31.0
14	Hamilton Clay Loam	0-6	Mineral soils	2.6	7.5	1.6	9.2	0.8	14.1	10.4	88.0
15	Horitiu Sandy Loam	0-6	"	2.6	7.6	2.1	11.4	2.9	9.2	6.8	81.7

TABLE II. CHANGES IN ORGANIC MATTER COMPOSITION WITH INCREASE IN DEPTH

(Expressed as a percentage of ash-free material)

Depth of Sample	1	2	3	4	5	6	7
	Waxes, Resins, etc.	Carbohydrate		Humic acids		Ligno-Humin	Ash (%)
		Hemi-cellulose	Cellulose	Carbonate Soluble	Hyroxide Soluble		
Moanatuatua series							
0-6 in.	6.2	20.7	8.5	2.4	9.0	31.2	3.1
3 ft.	10.0	13.3	6.4	3.6	15.4	24.6	3.1
8 ft	10.6	4.7	4.0	14.8	24.7	18.1	7.3
13 ft	10.8	5.4	3.4	13.0	21.9	16.2	5.0
18 ft	10.9	4.9	2.3	10.4	33.2	23.6	4.1
23 ft	9.0	4.6	3.0	18.7	26.1	14.2	10.1
Rukuhia series							
0-2 in.	9.0	6.2	2.0	14.7	11.4	14.8	32.0
4-6 in.	10.5	6.0	1.6	16.7	12.9	24.0	24.8
3 ft	12.3	5.7	2.6	8.0	21.6	17.0	9.0
6 ft	13.4	5.3	2.9	16.1	23.3	23.7	5.0
8 ft	13.5	3.4	0.8	14.7	35.0	18.1	6.0
13 ft	11.7	3.8	4.0	11.7	26.0	24.5	9.6
18 ft.	11.4	4.1	3.4	25.6	27.0	16.4	15.1
23 ft	9.7	3.3	2.5	12.6	16.2	13.0	5.3

The ash content of the peats in the two series, are similar and show an expected increase down the profile. The higher ash content of the surface Rukuhia peat is no doubt due to accumulation as a result of the more rapid oxidation which has occurred.

In the shallow highly decomposed Ruakura peat the position is similar. The results in Table I, Samples 10-13, suggest that this peat has reached an advanced stage of decomposition which is constant for the whole depth of the peat. The carbohydrate level is similar to that of the deeper peats described in Table II. It has apparently reached the same static level. With the humic fractions, however, oxidation has continued and not only is the total humic-acid content high but it has been almost completely converted to carbonate-soluble humic acid. This further confirms the idea that a chemical oxidation of the humic acid has continued after the bacterial removal of the carbohydrate material.

Nitrogen Status of the Peats

Whenever possible, total nitrogen analyses were carried out on the peats and on the acid hydrolysates. However, no marked trends were

observed. The total nitrogen figures ranged from 1.0 per cent for the Ruakura samples and 1.2–1.5 per cent for the Rukuhia samples to 1.8-1.9 per cent for the undecomposed Hauraki and Moanatuatua peats. In general, between 30 and 50 per cent of the total nitrogen was dissolved by the acid extractions, and always one half to two thirds of this was soluble in the weaker hydrochloric acid. No general trends in the amount of acid-soluble nitrogen could be noted. The fact that a large proportion of the nitrogen was not dissolved, even by five hours boiling with 7 per cent (w/w) sulphuric acid, suggests that much of the original plant protein has been rendered chemically inert, probably by combination with the humic and ligno-humin compounds.

In contrast, it is of interest to note that in a sample of Bay of Plenty peat, on which field officers claimed that perennial ryegrass (*Lollium perenne*) would grow well without associated clovers or added nitrogen, 84 per cent of the 1.52 per cent of nitrogen was soluble in the acid extracts.

Conclusions

In the absence of chemical oxidation induced by continual cultivation, the most likely way in which the surface layers of the peat would be decomposed to liberate their unavailable nitrogen is by aerobic bacterial activity. The conditions governing such activity are: correct pH, mineral nutrients, oxygen, and energy material, i.e. carbohydrate. Under the anaerobic conditions which have governed the natural development of the peat it appears that the peat has been decomposed without breakdown of the nitrogen compounds. It is also questionable whether the large accumulation of humic acids would occur under aerobic conditions.

Of the conditions listed above, the control of the pH and mineral nutrients is readily obtained in normal farming development of peat. However, the supply of energy material for soil bacteria is an aspect which has not been considered and which would entail modifications of existing farming practice. It is therefore suggested that the raw peats which contain relatively large amounts of carbohydrate, should, when the other conditions are fulfilled, decompose readily to release their nitrogen supplies. The decomposed peats, however, which are much lower in carbohydrate are less likely to decompose in the required manner. It is assumed that the humic acids, which are probably formed by chemical oxidation, are not suitable material for bacterial growth.

The position can be further emphasised by comparing the amounts of potential biologically available material (carbohydrate) and probably inert compounds (humic acids and ligno-humin). If the ratios of available to inert organic matter are calculated from the amounts of these compounds listed in Table I the following series is obtained:

Location	Sample No.	Ratio
Moanatuatua (raw)	1	.7
Hauraki (raw)	3	.4
Rukuhia (decomposed)		.2
Ruakura (decomposed)	11	.1
Mineral Soil	14 & 15	.4

These figures show that the composition of the organic fraction of the raw peats is nearer to that of a mineral soil than is the organic

matter of the decomposed peat. They confirm the suggestion that under the conditions specified the raw peat is more likely to decompose in the required manner.

So far as the conversion of the lignin to humic compounds is concerned, the results given in Table I confirm the deductions put forward. The results from Table II suggest that this conversion is a continuous chemical oxidation. The completion of the final step from hydroxide-soluble humic acid to carbonate-soluble humic acid, however, appears to be more rapid in the aerated surface layers.

Further work on the distribution of the various fractions and their chemical constitution will be carried out.

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REFERENCES

1. THOMPSON, F. B. and ELLIOT, I. L., 1950: The Development of Waikato Peat Soils. *N.Z. J. Sci. Tech., B31*: 1-16.
2. ————, 1950: The Development of Peat Land. *N.Z. J. Agric. 80*: 101-8.
3. ———— and ADAM, J., 1952: The Development of Peat Soils. *Ibid. 84*: 4-10.
4. HARRIS, W. F. and FILMER, D. W., 1946: A Peat Profile in the Agricultural Area, Hauraki Plains, New Zealand. *N.Z. J. Sci. Tech. B28*: 1-19.
5. WAKSMAN, S. A., 1938: Humus, pp. 424-8. William & Wilkins, Baltimore.
6. ———— *Ibid*, pp. 160-9.
7. FORSYTHE, W. G. C., 1947: The Characterization of Humic Complexes of Soil Organic Matter. *J. Agric. Sci. 37*: 132-8.
8. SOMOGI, M., 1945: A New Reagent for the Determination of Sugars. *J. Biol. Chem. 160*: 61-68.
9. DOAK, B. W., 1939: A New Method for Clarification of Plant Extracts for the Determination of Reducing Sugars. *N.Z. J. Sci. Tech. B21*: 90-95.
10. WHITE, E. P., THOMPSON, F. B. and BRICE, N., 1948: Application of the Dumas Micro Method to Pasture Nitrogen Analyses. *Analyst, 73*: 146-8.

LIFETIME WOOL PRODUCTION AND BREEDING PERFORMANCE OF ROMNEY MARSH AND CORRIEDALE EWES

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Summary

Lifetime records of fleece weight and breeding performance for 336 ewes in two flocks have been analysed. There were ram (sire) differences in the commercial Romney stud flock in hogget, fifth fleece and lifetime production of wool, the best rams being those bred in the flock; but no ram differences were found in the Corriedale Merit Sire Test ewes.

The well-known age differences in fleece weight and fertility are illustrated.

Correlations of hogget and mature or lifetime average fleece-weight have been found and compared with previously reported figures. The hogget-lifetime correlation of the Corriedales was 0.84, showing that selection on hogget fleece weight is fairly reliable. The heritability of fleece weight is generally accepted as being low; an estimate of 0.52 from the present material is not to be taken seriously, but it is suggested that fleece-weight heritability may well be higher in Corriedales than in other breeds.

Ewes born as singles clip as hoggets significantly more wool (0.27 ± 0.12 lb) than ewes born as twins. The latter have significantly more multiple births, producing in their life 0.4 more lambs per ewe.

Introduction

Few studies of lifetime wool production in sheep have been reported. Average fleece weights at different ages have been found, but few attempts have been made to obtain or analyse series of records from individual sheep in the way made familiar for dairy cattle by herd recording.

The repeatability of fleece weight in the first three fleeces is usually about 0.5 (Rasmussen, 1942). Terrill (1939) found a correlation of 0.59 ± 0.04 between the yearling and average of first four mature fleece-weights of Rambouillet ewes. Wolf (1951) correlated yearling fleece-weight with the average of all (four to seven) fleece weights for 686 Merino-Land sheep; the correlation, 0.6274 ± 0.0142, should actually be 0.6279 ± 0.0231. Wolf quotes a similar result, 0.61 ± 0.04, from a study in Mutton Merino sheep by Gärtner and von Ungern-Sternberg (1938). As the yearling fleece-weight is apparently included in Wolf's lifetime average some correlation is inevitable, and if in fact there were no relation between yearling and later fleece weights Wolf would still have found a yearling-lifetime correlation of roughly 0.45 ± 0.03. This does not detract from the value of his results.

In the present paper lifetime records of fleece weight and breeding performance of two groups of ewes are investigated. The "Rinaultrie" Romney Marsh stud flock from which the first group were drawn has been described by Stevens and Wright (1952). The farm is in Mid-

Canterbury, near the foothills. The second group comprises the ewe lambs produced in the first Corriedale Merit Sire Test, run by Lincoln College for the Corriedale Sheep Society (Stevens, 1949).

ANALYSIS AND RESULTS

1. *Rinaultrie Ewes*

(*a*) *The material*: Records were available for all ewes born in the flock in 1944 and 1945 and entering the breeding flock in 1946 and 1947 respectively. They show whether the ewe was a single or a twin, its hogget fleece-weight and subsequent fleece weights and lambing records up to 1950. Lambs were shorn in February, hoggets in October and the main flock in November-December; the hogget fleece, therefore, represents about eight months' growth and the second fleece rather more than a year. Numbers of ewes surviving to shearing each year are shown in Table 1.

TABLE I. NUMBER OF EWES ENTERING FLOCK IN 1946 AND 1947, AND NUMBER SHORN EACH YEAR TO 1950

	1946	1947	1948	1949	1950
Ewes born 1944	97	82	75	50	3
Ewes born 1945	—	114	108	94	71

(*b*) *Fleece weights*: If the records had been complete, 50 of the 97 ewes entering in 1946 would have had five fleece weights for analysis; actually only 43 of these and 54 of the second group could be fully analysed, these forming less than a third of the whole flock over the period. All fleece weights were adjusted for lambing performance, figures for ewes bearing twins being increased 0.4 lb and those for dry ewes decreased 1.0 lb, these being the average differences in this flock for the period 1943-1950 (Stevens and Wright, 1952). With these adjustments the average fleece weights for the ewes of each age were as shown in Table II.

TABLE II. AVERAGE FLEECE WEIGHTS FOR EWES WITH COMPLETE RECORDS.

	Hgt.	2nd	3rd	4th	5th
Ewes born 1944	7.05	10.85	9.95	9.73	9.43
Ewes born 1945	7.84	11.03	9.65	9.31	8.96
Difference	—.79**	—.18	0.30	0.42	0.47*
†S.E. of difference	0.23	0.27	0.28	0.24	0.22

(† Standard error derived from variance within ram progenies.)

The difference between the two groups of hoggets may be entirely a seasonal difference, as the 1945 average fleece weight for the whole flock was 0.8 lb below the average for 1946-1950.

The 97 ewes were the offspring of 13 rams, 3 rams having progeny in both groups, and the records were analysed for ram differences (twelve degrees of freedom; confounded with year of birth), year differences (one degree of freedom, within the 3 rams which were used twice) and ram-year interaction (two degrees of freedom). From this analysis it was found that in the hogget records the year difference was highly significant ($F_{1,81} = 18.0$; 1 per cent level, 7.0), but that for the fifth fleece there was no year difference (none was expected; the seasons 1949 and 1950 were similar) and therefore a

significant variance ratio for rams ($F_{12,81} = 4.12$; 1 per cent level, 2.41) could be taken at its face value. The analysis of total lifetime wool production is given in Table III, and shows real differences between progeny of different rams. The nine Rinaultrie-bred rams contained the best seven and the worst ram. Averages ranged from 8.3 lb to 10.9 lb with standard errors between 0.3 and 0.6 lb.

Table III. Analysis of Variance: Total Lifetime Wool Production of 97 Ewes.

Comparison	d.f.	M.S.	F
Between rams	12	68.88	2.77 **
Year of birth (for 3 rams)	1	43.55	1.75
Year x Rams (for 3 rams)	2	10.72	—
Within rams	81	24.83	

A separate analysis of *all* hogget records (179 fleece weights) gave averages for the two years of 7.10 and 7.85 lb, with no significant ram differences in the first year, and one ram highly significantly below the rest in the second. In this analysis the difference between hoggets born as single lambs and as twins was also examined. Singles averaged 0.24 ± 0.15 lb higher than twins, a difference approaching significance if it is considered that singles could not possibly have averaged lower than twins.

(*c*) *Correlations*: Various correlation coefficients were found, without adjusting for the seasonal difference in hogget fleece weight. Overall correlations of hogget fleece weight with the second and fifth fleece weights, the sum of the four mature fleece weights and the sum of five fleece weights (lifetime wool production, including hogget) were 0.51 ± 0.08, 0.35 ± 0.09, 0.44 ± 0.08, and 0.62 ± 0.06. Coefficients calculated within year of birth were roughly 0.05 higher. For the 95 sheep with less than five fleece weights recorded, the correlations of hogget fleece weight with the average of others and the average of all fleece weights were 0.48 ± 0.08 and 0.75 ± 0.05, which are higher than those for full records. Although it is partly spurious, the correlation of hogget with total lifetime fleece weight is the most useful of these figures. It shows that almost 40 per cent of the variation in lifetime production is associated with variation in hogget fleece weight, or that if ewes could be selected of uniform hogget weight their lifetime production would still have 60 per cent of the variability of an unselected line. In other words, hogget fleece weight is a reasonably useful index for selection for lifetime wool production.

(*d*) *Multiple births*: Of the 97 ewes born in 1944 and included in this study, 40 were singles and 57 were twins or triplets; 52 of the 114 born in 1945 were singles—a similar proportion. Only six rams had enough progeny for a test for differences between rams in their proportions of singles, and the test showed no differences (chi square for five degrees of freedom, 7.50). The 92 ewes which were singles produced in their life 193 single lambs and 89 pairs of twins, but the 119 ewes which were twins or triplets produced 220 singles, 149 pairs of twins and one set of triplets, a significantly higher proportion of multiple births (at 2 per cent level). There was no difference in the proportions of singles and twins surviving to the fifth year. The actual numbers of births per ewe recorded in each group were 3.07 and 3.11,

a negligible difference, but the numbers of lambs per ewe were 4.03 and 4.38. The proportions of births which were multiple in the ewes at different ages from two-tooth (second year) on were for single ewes: 0.14, 0.34, 0.34, 0.48; and for twin or triplet ewes: 0.20, 0.50, 0.50, 0.48, illustrating the well-known increase in fertility with age (c.f. Hart and Stevens, 1953). The differences between groups in the second and third of these figures are significant (the separate values of chi square are 1.0, 4.5, 4.4 and 0.002), and although this must be discounted somewhat because the succeeding figures are correlated in that each is based largely on the same ewes as provide the following figure, it is clear that up to their fourth year single ewes are less fertile, and in the fifth year there is no difference. As a check, the ewes surviving to the fifth year had in the third year proportions of multiple births of 0.38 and 0.55.

2. *College Ewes*

(*a*) *The material*: Records similar to those from Rinaultrie were available from the Corriedale Merit Sire Test ewes born at Lincoln College in 1947. The dam's fleece weight in 1947 (fifth fleece), and the fleece weights and lambing behaviour up to 1951 were analysed. There were 125 ewes, the numbers of fleece weights recorded in the years 1948 to 1951 were 120, 99, 100, 76, and there were 68 complete records. Corrections for lambing behaviour were applied as above; seasonal corrections could not be made and in this case are not necessary for correlations or group comparisons.

(*b*) *Fleece weights*: The 68 ewes with complete records (dam's and own four fleece weights) were sired by ten rams. Differences between ram groups in average dam fleece weight fortunately did not approach significance, but neither did differences in hogget fleece weight or in the mean of the three later fleece weights. The ten group mature-fleece averages ranged from 8.9 to 10.1 lb per fleece. Average hogget fleece weights (sheep about 12 months old, not shorn as lambs) for sheep with 0, 1, 2 and 3 consecutive mature fleece weights recorded were 10.4, 9.5, 9.7 and 9.4 lb, showing no consistent trend, and for singles and twins were 9.74 and 9.42 lb, a difference approaching significance.

(*c*) *Correlations and regressions*: The overall correlation of hogget and dam fleece weight was 0.19 ± 0.12—not significant; of dam and mature average, 0.26 ± 0.12—significant at the 5 per cent level; of hogget and mature average, 0.72—highly significant. The corresponding regression coefficients were 0.18, 0.23 and 0.68. The multiple regression of mature average on dam and hogget fleece weight was not significantly better than the regression on hogget weight alone. This was:

Mature average = 0.68 (hogget weight) + 3.07 ± 0.71 lb,

so that, for instance, for a hogget weight of 10.0 lb the mature average under these seasonal conditions is fairly certain to be between 8.5 and 11.3 lb, and if the hogget weight is 7.0 lb, the mature average is unlikely to be above 9.3 lb.

An estimate of heritability of mature average fleece weight may be obtained by doubling the regression on dam's fifth fleece weight. The result, 0.46 ± 0.21, is presumably lower than would be obtained if

dam's mature average were available. Within-sire regressions on dam's fleece weight were slightly higher, and the corresponding estimate of heritability, which is more appropriate, is 0.52 ± 0.22. For reasonable precision in the estimate a sample of 400 to 500 sheep would be needed.

The spurious correlation of hogget fleece weight with lifetime wool production was 0.84, with 5 per cent limits 0.75 and 0.89; accordingly, 70 per cent of the variation in total weight of the first four fleeces is associated with variation in hogget fleece weight. Obviously, it is not appropriate to quote a standard error for this correlation.

(*d*) *Multiple births*: Of the 125 ewes, 90 were singles and produced 119 singles and 58 pairs of twins, and the 35 which were twins gave 41 singles and 32 pairs of twins. The respective numbers of lambings per ewe were 1.97 and 2.09, a difference too small to mean anything, and the numbers of lambs per ewe were 2.61 and 3.00, a difference approaching significance at the 5 per cent level. The proportions of multiple births at the three ages for the two groups were 0.25, 0.34 and 0.40, and 0.33, 0.39 and 0.58 respectively; age differences were significant but group differences at each age were not.

Discussion

The numbers of ewes with full records for analysis were smaller than is desirable, and many of the second group had not completed their useful life; however, the groups agree in many respects and valid conclusions can be drawn.

The numerical and practical values of the correlation between hogget and average mature fleece weights depend on the number of mature fleeces recorded; the more fleeces, the lower the correlation but the more useful is the information for selection programmes. The hogget and mature average (average of three) correlation of 0.72 for the College sheep is the highest so far reported; this is partly because all sheep were the same age, and the correlation is practically independent of seasonal fluctuations. The correlating of hogget and mature average (of four) for Rinaultrie within year of birth removed a real seasonal effect, but even so the coefficient was only raised from 0.44 to 0.50, which is not a significant increase. If the present study had extended to ewes born in several seasons, it is considered that the College flock correlation would have been close to that found by Terrill (1939), and the Rinaultrie correlation close to Wolf's (1951). The latter conclusion assumes that Wolf's correlation is, as reported, "spurious" and recognises that he omitted results from a particularly atypical (favourable) season from his analysis and that his data were from several flocks.

The information obtained on ram differences in progeny performance, on age differences in fertility and wool growth, and the hogget-lifetime fleece-weight correlation is not new, but it illustrates the need and the prospects for selecting ewes early in life, so as to raise the average age of the flock, and hence the fertility. The estimate of 0.52 for heritability of fleece weight is almost certainly too high, particularly as it is indirect. Rae (1948) found estimates from 0.10 to 0.15 by the usual methods applied to a Massey College Romney flock, and Rasmussen (1942) found estimates from 0.14 (Romney) to 0.56 (Corriedale).

The heritability depends of course on the genetic variability existing in the flock, and differences in estimates between flocks, as between breeds, are not surprising. It is tempting to suggest that fleece weight heritability in Corriedales is really higher than in Romneys; the explanation would be very simple.

No reference has been found in the available literature to differences in the lifetime production of ewes born as single lambs and as twins. The differences found in the present study are several: (1) a difference in hogget fleece weight in favour of singles of 0.24 ± 0.15 lb (Rinaultrie) and 0.32 ± 0.21 lb (College), an average of 0.27 ± 0.12, which is significant at the 5 per cent level; (2) a difference in numbers of lambs produced (4.03 and 4.38 for Rinaultrie, all ewes up to five years old, and 2.61 and 3.00 for College, all ewes up to four years old); and (3) related differences in proportions of multiple births at different ages. Except as five-year-old ewes, the twins had more multiple births at all ages. The Rinaultrie twins reached their maximum fertility at three years, but this was probably accidental; the three other groups all showed a continuous increase with age. Singles and twins showed no difference in average numbers of lambings, nor in survival.

REFERENCES

GARTNER, R., and VON UNGERN-STERNBERG, 1938: Korrelationen zwishen den wichtigsten Leistungen des Merino-Fleischafes, *Z. Schafz.*, *27*: 81-85. (Seen only as Abstr. in *Animal Breed. Abstr. 6*: 110, 1938).

HART, D. S. and STEVENS, P. G., 1953: Observations on Non-Nutritional Factors Affecting Fertility in Sheep. *Proc. N.Z. Soc. Anim. Prod. 12*: (in press).

RAE, A. L., 1948: Some Aspects of Progeny Testing in Sheep. *Proc. N.Z. Soc. Anim. Prod. 8*: 97-104.

RASMUSSEN, K., 1942: The Inheritance of Fleece Weights in Range Sheep. *Sci. Agric. 23*: 104-16.

STEVENS, P. G., 1949: The Merit Sire Test of the Corrieedale Sheep Society (Inc.). *Lincoln Coll. Tech. Publ. No. 3.*

————, and WRIGHT, G. M., 1952: Some Variations in the Fleece of Romney Marsh Stud Ewes. *Proc. N.Z. Soc. Anim. Prod. 11*: 18-22.

TERRILL, C. E., 1939: Selection of Range Rambouillet Ewes. *Proc. Am. Soc Anim. Prod. 32*: 333-40.

WOLF, G., 1951: Kann aus dem Jährlingsschurgewicht auf das durchschnittliche Lebensschurgewicht beim bayerischen Merino-Landschaf geschlossen werden? *Züchtungskunde, 22*: 183-9. (Summary in *Anim. Breed. Abstr. 19*).

PHOTOSENSITIVITY DISEASES IN NEW ZEALAND

VII. THE APPLICATION OF THE GLUCOSE-TOLERANCE TEST TO SHEEP AND SOME ASPECTS OF CARBOHYDRATE METABOLISM IN SOUTHDOWN CONGENITAL PHOTOSENSITIVITY.

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Summary

An intravenous glucose-tolerance test has been applied to sheep, and normal values determined for Southdowns and Romneys.

The importance of eliminating the effects of nervous excitement in animals used for work involving determinations of blood glucose is emphasized.

It has been shown that there is no difference in glucose tolerance between normal and congenitally photosensitive Southdown sheep.

Measurements of the blood-glucose response to intravenous adrenalin and insulin indicated an inability of the liver of the photosensitive animals to mobilize and supply glucose to the bloodstream. The observed effect was small, but is an indication of the presence of a liver dysfunction involving glucose metabolism in Southdown congenital photosensitivity.

Introduction

The glucose-tolerance test is primarily a test of the ability of include an examination of some aspects of carbohydrate metabolism in the normal and photosensitive Southdown.

The glucose tolerance test is primarily a test of the ability of the liver to decrease the production and supply of glucose to the blood stream in response to an imposed hyperglycaemia. As a liver-function test it is complicated by other factors, and in view of the large capacity of the liver, a glucose-tolerance test is not the most sensitive of tests for the detection of liver damage, since the damage must be relatively large before glucose metabolism is seriously interfered with. However, with Southdown photosensitivity, we are not dealing with an extensive liver damage but rather a liver dysfunction and it appeared possible that the glucose-tolerance test might give useful information.

In applying this test to sheep, the oral route of administration was ruled out. Phillipson and McAnally[2] have shown that glucose is almost completely broken down in the rumen, and that it is not absorbed as such by the animal in any significant amounts. Furthermore, in the sheep, there is no marked alimentary hyperglycaemia produced after oral glucose or after normal feeding. For a test on man, a fasting period is specified in order to avoid the effects of alimentation. In the ruminant, where the rumen does not empty merely on a short term fast, a fasting blood-glucose value is virtually meaningless, since the value does not come down to a "steady" state, but continues to fluctuate.

METHOD OF CONDUCTING INTRAVENOUS GLUCOSE-TOLERANCE TEST ON SHEEP

The following is a description of the procedure used in making an intravenous glucose-tolerance test on the sheep. The animal was treated as gently and quietly as possible. The wool round the neck in an area over the jugular veins was clipped short, and a preliminary blood sample taken into a glass vial containing sodium fluoride as an anti-coagulant and inhibitor of glycolysis. A syringe containing the dose of glucose as a 50 per cent solution in water, was then connected to the needle and injection commenced. The total time for the injection was one minute, zero time being taken when half the dose had been given. Subsequent sample bleedings were then made from the vein on the opposite side to avoid possible contamination with concentrated glucose solution, at times of 2, 30, 60, 90 and 120 min. after injection. It was found convenient to conduct tests on three sheep together, with 5-min. intervals between the starting times of each. In between bleedings, blood filtrates were prepared using Somogyi's[3] barium-hydroxide-zinc-sulphate method of protein precipitation. Blood glucose was then determined as soon as possible with Somogyi's reagent[4] in conjunction with Nelson's[5] colorimetric determination of the cuprous oxide formed.

In the early stages of this work, trials were made in order to find a suitable dose level and appropriate bleeding times. The dose chosen was such that a definite hyperglycaemia was produced, which in the normal animal returned to the pre-injection blood glucose level within two hours. Urine tests were done on several sheep in order to obtain some idea of the amount of loss of injected glucose by renal excretion.

TABLE I. GLUCOSE-TOLERANCE TEST ON A ROMNEY EWE
(Weight, 38 kg; Glucose Dose, 0.43 g per kg body weight)

Time (min)	0	2	30	60	90	120
Blood Glucose (mg%)	52	155	131	103	74	55
Urine Volume (ml)	27	—	99	95	—	62
Urine reducing sugar (g%)	0.02	—	1.04	0.29	—	0.06
Sugar excreted (g)	0.01	—	1.03	0.28	—	0.04

Table I gives the data for a typical glucose-tolerance test on a 48-kg Romney ewe which received a dose of 0.43 g glucose per kg body weight. A mild glucosuria was present in the sample collected over the first 30 min. during the period of maximal hyperglycaemia. The amount of glucose lost in the urine over the whole test was only about 10–12 per cent of the dosed material. This dose rate was therefore chosen; it could have been made slightly lower,

but in a test of this nature it was better to be certain that the given dose constituted a definite overload. Although this run of tests was not particularly designed to determine the renal threshold of the ewes for glucose, the results obtained indicate that it is in the vicinity of a blood-glucose level of 100 mg per cent.

The animals used for these tests and the method of management have been described in the previous paper[1].

TABLE II. GLUCOSE-TOLERANCE TESTS ON PHOTOSENSITIVE SOUTHDOWNS AND NORMAL SOUTHDOWNS AND ROMNEYS

Time (min)	0	2	30	60	90	120
Southdowns						
Photosensitive						
S.46	51	296	111	52	29	37
S.79	57	261	104	55	25	25
D.485	61	206	116	80	54	46
Group Mean	56	254	110	62	36	36
Normal						
A.12	44	303	154	108	73	60
B.26	49	259	120	80	50	52
17	55	241	133	113	87	67
Group Mean	49	268	136	100	70	60
Romneys						
Normal						
104	53	200	110	76	56	58
108	65	196	125	106	98	80
117	52	155	131	103	74	55
127	54	192	108	84	69	64
129	56	215	124	90	60	65
179	58	235	133	92	72	65
Group Mean	56	199	122	92	72	65

RESULTS

Glucose-tolerance tests made on two groups of three normal and congenitally photosensitive Southdown sheep are shown in Table II. Individual sheep in each group gave blood-glucose values lying close to the mean, and although the difference between groups was small, it was repeatable. Tests on a group of six normal Romneys yielded a set of values very similar to those obtained for the group of normal Southdowns, and it appeared at the time that these results could be interpreted as showing a small but definite increase in glucose tolerance on the part of the photosensitive Southdowns. Since this might have been indicative of a

slight adrenal insufficiency, values for serum sodium, potassium and blood chloride were determined. No difference between normal and photosensitive animals was found.

Range

Serum sodium: 333–348 mg/100 ml
Serum potassium: 16.3–18.7 mg/100 ml
Blood chloride: 279–300 mg.Cl/100 ml

The first sets of glucose-tolerance tests were done in April, when the increased tolerance to glucose on the part of the photosensitive animals relative to the normals was observed—or rather, the normals were showing a decreased tolerance in comparison with the photosensitive sheep. Repetition of the tests in May still showed a decreased tolerance in the normals but not as large as in April. The work was discontinued at this stage, and on taking it up again in April of the next year, the normals were showing only a slightly decreased tolerance compared with the photosensitive sheep. In May the tests showed no difference between the two groups (Table III). Other liver-function tests were conducted on these animals during April and May, between the first and second sets of glucose-tolerance tests of each year.

The possible effects on the result for a given test of the various liver-function tests, previously applied to the same animals, caused some concern. However, the change in response observed was not caused by the application of some or all of the other liver-function tests, since the photosensitive animals which underwent the same series of tests showed no shift in glucose tolerance.

TABLE III. GLUCOSE-TOLERANCE TESTS ON TRAINED NORMAL SOUTHDOWNS, COMPARED WITH PHOTOSENSITIVE SOUTHDOWNS

Time (min)	0	2	30	60	90	120
Normal						
A.12	45	314	121	75	48	41
B.26	43	251	88	47	34	32
64	37	250	89	44	29	36
Group Mean	42	272	99	55	37	36
Photosensitive						
S.46	44	284	108	55	33	34
S.79	50	291	123	75	47	33
D.485	45	265	130	72	44	31
Group Mean	46	280	120	67	41	33

It was thought that the explanation might lie in the previous history of the Southdowns. The photosensitive animals came originally from Ruakura Animal Research Station where they had become accustomed to handling. The normal Southdowns and

Romneys used as controls came from the Wallaceville flock where, until brought in for the series of tests, they were not subject to much human contact. It appears that during the period following the initial glucose-tolerance tests the normals underwent a period of "training" which has been reflected in the results of subsequent glucose-tolerance tests. The lowered tolerance shown initially, was presumably a normal glucose-tolerance curve superimposed upon an adrenalin hyperglycaemia produced by nervous excitement due to unaccustomed procedure.

Table IV. Sham Glucose-Tolerance Tests. Injection of Normal Saline instead of Glucose

Time (min)	0	2	30	60	90	120
Trained sheep						
a	38	38	42	43.5	39.5	40.5
b	24	23.5	24	26	27	27
c	31	29	32	30.5	31	31
Untrained sheep						
d	60	61	74	76	69	50
e	70	68	68	63	61	52
f	52	52	52	49	44	39

An attempt to confirm this effect of "training" was made on a normal Romney brought in from the field. It was given a glucose-tolerance test on the first day. Here the preliminary blood-sugar value was high indicating adrenalin-induced hyperglycaemia, and the test indicated a markedly decreased tolerance. This animal was kept in a pen for fourteen days, where it was subjected to frequent handling. Further tests done on the seventh and fourteenth days showed an increasing tolerance to glucose, following the same direction as that taken by the normal Southdowns. This series was not carried further, but with a longer period of "training" it seemed fairly certain that the glucose tolerance would approach that of the normal Southdowns.

Sham glucose-tolerance tests on trained and untrained sheep proved quite instructive. In these, physiologically normal saline was injected instead of a glucose solution. All other details of the test were the same (Table IV). With the trained sheep, there was little or no shift in the blood-glucose level over the two hour period, while the untrained animals exhibited an initial hyperglycaemia at the preliminary bleeding and a rise and subsequent fall in blood-glucose values during the test.

At this stage it was considered desirable to extend the investigation of the carbohydrate metabolism of these animals by measuring their response to insulin and adrenalin.

Blood-Glucose Response to Intravenous Adrenalin

The presence of adrenalin in the blood stream leads to a hyperglycaemia due to mobilization of stored liver glycogen, and the conversion of muscle glycogen to lactic acid which then undergoes glycogenesis in the liver. The hyperglycaemic response to injected adrenalin has been used to measure the comparative levels of liver glycogen reserve in cows[6]. Lower blood-sugar curves after adrenalin have been reported in human liver damage and in obstructive jaundice, than in normals[7].

Preliminary trials on sheep showed that a dose level of 2 ml of a 1 : 20,000 aqueous solution of adrenalin on intravenous injection resulted in a conveniently measurable rise in the blood-glucose level. The procedure for these tests was similar to that for the glucose tolerance test; sampling times were altered to provide better coverage of the initial hyperglycaemic period. The main difficulty in comparing the results on normal and photosensitive Southdowns was to match animals of similar body weight. Comparison has been made on animals with body weights of 46 to 49 kg in Table V.

TABLE V. BLOOD GLUCOSE RESPONSE TO INTRAVENOUS ADRENALIN

Time (min)	0	4	8	15	30	60
Normal Southdowns						
Dose: 2 ml 1 : 20,00 Adrenalin						
A.12 64 kg	40	51	51	54	56	57
A.12 65 kg	40	59	62.5	51.5	54	56
B.26 47 kg	37.5	46	60.5	58	59	57
B.26 48 kg	42.5	52	61.5	72.5	45	44.5
17 47 kg	39	47	57	55	59.5	62.5
Mean B.26 & 17 figures	39.7	48.3	59.7	61.8	54.5	54.7
Mean body wt. 47.3 kg						
Mean rise above preliminary blood-glucose level	0	8.6	20.0	22.1	14.8	15.0
Photosensitive Southdowns						
Dose: 2 ml 1 : 20,000 Adrenalin						
S.46 49 kg	53	60	68	75	75	73
S.46 49 kg	50	57.5	58.5	56.5	60	56
S.79 46 kg	61	65.5	69	71	70	62.5
S.79 46 kg	50	58.5	58.5	62.5	60.5	58
Mean:	53.5	60.4	63.5	66.3	66.4	62.4
Mean body wt. 47.5 kg						
Mean rise above preliminary blood-glucose level	0	6.9	10.0	12.8	12.9	8.9

TABLE VI. BLOOD GLUCOSE RESPONSE TO INTRAVENOUS INSULIN

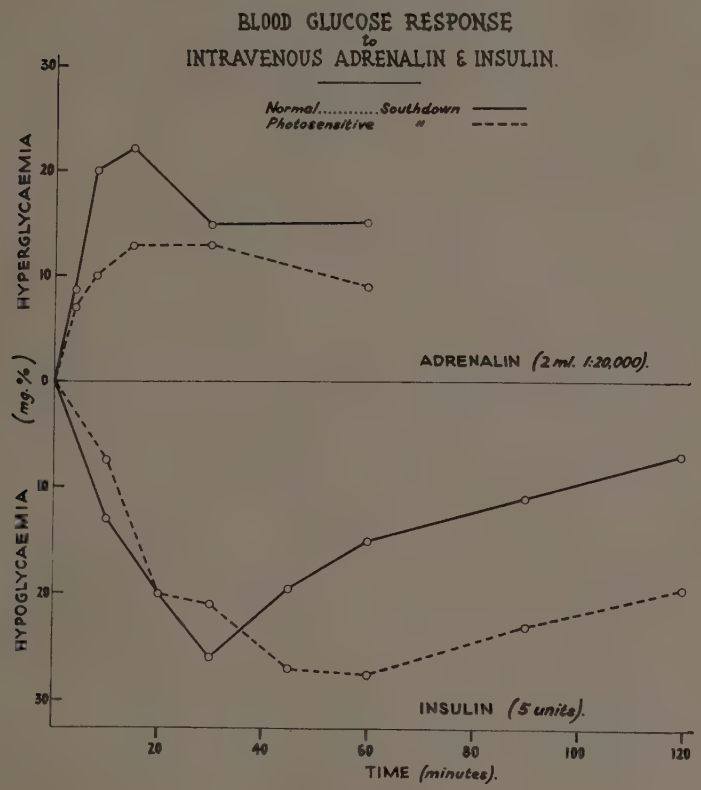
Time (min)	0	10	20	30	45	60	90	120
Normal Southdowns								
Dose: 5 units.								
B.26 48 kg	45	32	25	17.5	26	28	32	39.5
64 52 kg	47	34	27	22	27	33.5	38	38
Mean 50 kg	46	33	26	20	26.5	31	35	39
Mean decrease on preliminary blood glucose:	0	13	20	26	19.5	15	11	7
Photosensitive Southdowns								
Dose: 5 units.								
S.46 49 kg	51	44	29	28	25	26	34	37.5
S.79 46 kg	54	46	36	35	26	24	25	28
Mean 47.5 kg	52.5	45	32.5	31.5	25.5	25	29.5	33
Mean decrease on preliminary blood glucose:	0	7.5	20	21	27	27.5	23	19.5

There was a decreased degree of hyperglycaemia observed in the photosensitive animals compared with the normals. This is more clearly shown in Fig. 1 where the mean rise in blood glucose above the mean preliminary value has been plotted against time. It must be noted that when these observations were made, the animals were "trained"; both normal and photosensitive animals were giving the same glucose-tolerance curves, so that the difference in response to adrenalin cannot be due to excitement. Four other photosensitive animals available, ranging in weight from 15 to 20 kg, and at dose levels one half to one third of that given to the large sheep, exhibited a similar low response to adrenalin.

Blood Glucose Response to Intravenous Insulin

The insulin used was obtained from the Commonwealth Serum Laboratories. After taking a preliminary sample, a dose equivalent to 5 units of insulin was injected and the blood glucose followed by bleedings over a period of two hours. Results of tests on sheep of similar body weight have been given in Fig. 1, where the decrease in blood glucose relative to the initial value has been plotted against time. Rather similar curves were obtained for the smaller photosensitive Southdowns on a proportionately lower dose of insulin. These tests were also made when the glucose-tolerance test had been stabilized in the normal animals.

It appears that the photosensitive animals are slightly more sensitive to insulin than are the normal Southdowns. The rate of fall towards the hypoglycaemic level is approximately the same for both, but the photosensitive animals take slightly longer to reach their minimal value, and show a slower return to the normal blood-sugar levels.



DISCUSSION

According to recent views on the origin, utilization and regulation of the blood sugar, as summarized by Soskin[8], the main endogenous source of blood glucose is located in the liver. The blood-sugar level prevailing in an animal represents a dynamic balance between the rate of production by the liver, and the rate of utilization of glucose by the extrahepatic tissues. The factors controlling this balance are: (1) the blood-glucose level itself, high levels leading to a decreased production by the liver, while the converse applies to a low blood-sugar level; (2) the endocrine control exercised principally by the hormones of the anterior pituitary and pancreas; insulin lowering the liver threshold for the production of glucose, and the anterior pituitary hormones raising it.

The results of the present work indicate that the normal Southdown and Romney animals show a lower glucose tolerance than the photosensitive Southdown, and that after a period of training, the tolerance of the normals gradually increases until finally it is identical with that of the photosensitive animals, whose response had remained constant throughout the same series of tests.

It would thus appear from the results of the glucose-tolerance tests that there is no derangement in the photosensitive animals involving utilization of glucose by the tissues, nor in the ability of the livers of these animals to decrease the production and supply of glucose to the blood in response to a hyperglycaemia.

The slightly lower response to intravenous adrenalin indicates a decreased ability on the part of the liver of the photosensitive animal to mobilize liver glycogen.

The results of the experiments on insulin response support this idea (Fig. 1). After injection of insulin the fall in blood glucose down to the lowest level of hypoglycaemia proceeds at approximately the same rate in both groups of Southdowns. This portion of the curve may be regarded as a form of glucose-tolerance test, the insulin lowering the threshold for production of glucose by the liver, and the normal blood sugar level then constituting a relative hyperglycaemia which is reduced by increased utilization of blood glucose. The slightly greater degree of hypoglycaemia attained by the photosensitive Southdowns, considered in conjunction with the slower return toward the normal blood-sugar levels, indicates an increased sensitivity to insulin in these sheep.

The most prominent feature of the insulin curve is the slow return toward the normal level on the part of the photosensitive animals. This is interpreted as indicating a relative inability of the liver of the photosensitive animal to mobilize and supply glucose to the blood.

It must, however, be emphasized that the effects observed were small, and probably of little or no adverse consequence to the animal. With regard to the glucose-tolerance test, it may well be that the photosensitive animals are abnormal in the normality of their glucose-tolerance curves. At no time was there any sign of a decreased tolerance due to excitement on the part of these animals. To obtain from normal animals glucose-tolerance curves similar to those of the photosensitive sheep, a lengthy period of training was required, and even then the avoidance of any small nervous upset to the sheep was necessary during the test. This could be an expression of a relative adrenal insufficiency in the photosensitive animals, but such a theory is unlikely in view of the essentially identical levels of serum sodium, potassium and blood chlorides found in both groups. The available evidence appears to locate the disturbance in carbohydrate metabolism of the congenital photosensitive animals, but such a hypothesis is unlikely in view of the the mobilization and supply of glucose to the blood stream, i.e., the liver gluconeogenesis or glycogenolysis.

References

1. Jamieson, N. D. and Swan, J. B., 1952: *N.Z. J. Sci. Tech. 34*: 354-9.
2. Phillipson, A. T. and McAnally, R. A., 1942: *J. Expt. Biol. 19*: 199-214.
3. Somogyi, M., 1945: *J. Biol. Chem. 160*: 61-69.
4. Somogyi, M., 1945: *Idem. 160*: 69-73.
5. Nelson, N., 1944: *Idem. 153*: 375-80.
6. Shaw, J. C., 1943: *J. Dairy Sci. 26*: 1079-90.
7. Loeb, R. F., Reeves, E. B. and Glasier, H. P., 1931: *J. Clin. Invest. 10*: 19-31.
8. Soskin, S., 1941: *Physiol. Rev. 21*: 140-93.

EFFECT OF SHEEP DROPPINGS ON YIELD, BOTANICAL COMPOSITION AND CHEMICAL COMPOSITION OF PASTURE

III. RESULTS OF FIELD TRIAL AT LINCOLN, CANTERBURY, FOR THE YEARS 1944-1947

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Summary

(1) A mixed pasture grazed by sheep without the normal return of dung and urine resulted in an average annual production of 9,600 lb of dry matter per acre. This growth was dominated by red clover especially in the summer and autumn periods. Ryegrass and white clover contributed much less to the total production.

(2) Grazing with the normal return of dung and urine also yielded a total annual production of 9,600 lb dry matter per acre but the pasture which developed was one dominated by ryegrasses and other grasses with much less clover in the mixture. Red clover contributed less than $\frac{1}{8}$ of the total production of this pasture.

(3) Corresponding with this difference in botanical composition, were differences in seasonal production; summer growth with the treatment involving no-return of dung and urine was greater than that where there was full-return but the latter treatment produced much more growth in winter and spring.

(4) Chemical composition of the herbage showed considerable differences, the no-return pasture producing herbage higher in Ca but lower in K than that of the full-return treatment.

(5) Increasing amounts of lime and superphosphate showed increases in growth in both series, the response in the no-return treatment being greater than in the full-return treatment.

(6) There was no difference in wheat yields in two successive crops taken at the conclusion of the pasture trial.

Introduction

The trial reported in this paper was designed to repeat in a simple form the main treatments investigated in two previous trials[1,2,3] carried out at Palmerston North, to measure the effects of animal dung and urine on pasture.

Experimental Procedure

The trial was laid down in autumn, 1944, and continued until January, 1948. The site was one acre of flat land at the Grasslands Division Substation at Lincoln. The soil type is regarded as one of the best for pasture growth in Canterbury and is classified by the Soil Bureau as "Wakanui silt loam on sand"[4]. The particular area had previously been used for a cropping rotation of oats, wheat and peas by the Agronomy Division and the crop yields were indicative of the uniformity in soil fertility levels. The original uniformity of the area was also demonstrated by the production figures for all treatments during the early part of this trial. The area was sown on 25 March 1944 with the following seeds mixture.

Species	lb per acre
Pedigree short rotation ryegrass (*Lolium perenne X L. multiflorum derivative*)	5
Pedigree perennial ryegrass (*L. perenne*)	25
Certified timothy (*Phleum pratense*)	3
Certified cocksfoot (*Dactylis glomerata*)	10
Dogstail (*Cynosurus cristatus*)	5
Browntop (*Agrostis tenuis*)	5
Chewings fescue (*Festuca rubra var. Fallax*)	10
Pedigree montgomery red clover (*Trifolium pratense*)	4
Pedigree white clover (*Trifolium repens*)	3
Total	70

The area was fenced into eight paddocks, each of $\frac{1}{16}$th acre with surrounding stock races. Decoy areas were used to avoid undue stock congregation at fence lines, and so obtain as uniform grazing as possible[5]. The experimental area was then divided into two groups of four paddocks; one group of four was grazed normally by sheep so that there was full return of dung and urine (F.R.); the other group (N.R.) was grazed by sheep equipped with collecting apparatus[6], which enabled the dung and urine to be collected and discarded.

Within each group, lime and superphosphate were applied at different rates. This mixture was used to conform to the established practice of fertilizing Canterbury soils for pasture growth[7]. Superphosphate at the rate of 1 cwt per acre per year and lime at $2\frac{1}{2}$ cwt per acre per year were applied to one paddock of each group; the second pair received twice, and the third pair three times this amount, whilst the final two were the non-fertilized controls. The superphosphate was applied in the autumn of each year while the lime was applied every second year.

Grazing commenced in spring 1944 and followed the same rotational pattern as in the Palmerston North trial, each grazing period lasting from 5 to 7 days. Measurement of herbage growth and composition was as previously described, using two 10 ft x 4 ft protecting cages which were shifted to fresh positions after cutting at each grazing. For botanical composition samples were drawn from bulkings of 60 to 80 small areas cut at random from the whole paddock just prior to each grazing. Subsamples of these were then analysed and the quantity of each species determined on a dry-weight basis. Chemical analyses were made by the Plant Chemistry Laboratory using standard A.O.A.C. methods on aliquot bulkings, for annual periods, of the dried and ground herbage from the individual cuttings at each grazing.

At the conclusion of the pasture trial in January 1948, the whole area was ploughed, cultivated and sown to Cross 7 wheat in May 1948. Each paddock was harvested separately and determinations of yield of grain and straw were made. To obtain these yield measurements, five samples each of three drill widths and 72 in. long were taken from each paddock. The sheaves were weighed and then each sample was threshed separately in a small mill. Samples from these were mechanically dressed and the total yields of clean seed calculated. This cropping procedure was repeated

in the following year in order to obtain a measure of any residual fertility differences. No fertilizer or lime was applied to these wheat crops.

TABLE I. SOIL TEMPERATURES AND RAINFALL DURING TRIAL PERIOD
(Recorded at Lincoln College Station, ½ mile from experiment.)

	Soil temperature at 8 in. at 9 a.m. (°F.)	Rainfall	
		Total (in.)	Departure from 10 year average 1934-1944 (in.)
1944-45			
Autumn (March - May)	-	-	-
Winter (June - August)	-	-	-
Spring (Sept - Nov)	51.2	6.72	+ 1.08
Summer (Dec - Feb)	61.0	12.42	+ 6.26
TOTAL	-	-	-
1945-46			
Autumn	52.1	10.88	+ 4.49
Winter	40.5	8.63	+ 1.24
Spring	50.7	3.85	- 1.79
Summer	60.8	6.81	+ 0.65
TOTAL	51.0	30.17	+ 4.59
1946-47			
Autumn	53.8	6.83	+ 0.26
Winter	42.7	6.69	- 0.71
Spring	49.6	10.67	+ 5.04
Summer	59.8	7.41	+ 1.11
TOTAL	51.5	31.60	+ 5.70
1947-48			
Autumn	53.0	5.38	- 2.23
Winter	41.7	6.13	- 1.27
Spring	51.5	9.08	+ 4.53
Summer	63.1	6.30	+ 0.55
TOTAL	52.3	26.89	+ 1.48
Average for years 1945-48			
Autumn	52.9	7.69	+ 0.84
Winter	41.6	7.15	- 0.25
Spring	50.6	7.87	+ 2.59
Summer	61.2	6.84	+ 0.77
TOTAL	51.6	29.55	+ 3.95

TABLE II. YIELDS OF DRY MATTER PER ACRE FOR THE TOTAL TRIAL PERIOD

Main Treatment	Period	Yield of dry matter per acre with Subsidiary Treatments indicated				
		No added Fertilizer (lb)	1 cwt Super + 2½ cwt Lime (lb)	2 cwt Super + 5 cwt Lime (lb)	3 cwt Super + 7½ cwt Lime (lb)	Average for subsidiary treatments (lb)
No Return of Dung and Urine	May 1944 - 9. 1.45	4400	5600	5700	5400	5275
	10. 1.45 - 15. 1.46	8400	10200	10500	12500	10400
	16. 1.46 - 23. 1.47	6400	7900	7800	8400	7625
	24. 1.47 - 23. 1.48	7900	7900	7600	7700	7775
	Total: 10.1.45 - 23.1.48	22700	26000	25900	28600	25800
	Mean Annual: 1945-48	7566	8666	8633	9533	8600
	Relative Yields	100	114	114	126	114
Full Return of Dung and Urine	May 1944 - 9. 1.45	5500	4900	5400	6400	5550
	10. 1.45 - 15. 1.46	7700	7400	8800	11000	8725
	16. 1.46 - 23. 1.47	8500	8300	8600	9000	8600
	24. 1.47 - 23. 1.48	7700	8500	8600	8900	8425
	Total:10.1.45 - 23.1.48	23900	24200	26000	28900	25750
	Mean Annual: 1945-48	7966	8067	8667	9633	8583
	Relative Yields	105	107	114	127	113

Results

The results of the trial are presented in six Tables. Table I gives rainfall and soil temperature data as seasonal and annual averages. In Table II are summarized the annual yields of dry matter for all treatments together with the average and relative yields for the years 1945-48. Table III deals with seasonal productions for four tratments only, viz.,

N.R. No fertilizer
N.R. High fertilizer
F.R. No fertilizer
F.R. High fertilizer

for the last 3-year period of the trial. Details of the intermediate and low fertilizer treatments have been omitted in this and in the two subsequent tables because the results are as would be expected from the extremes presented.

The reasons for the differences in performance of the various plots are shown in the first half of Table IV while the annual yields of the different major species are given in the second half of the Table. Yield figures for the four major elements, nitrogen, calcium, phosphorus and potash, are presented as a series of annual totals. These have been calculated from the percentage composition data in Table V with the species yields of the first half of Table IV. Table VI is a summary of grain and straw yields for the two wheat crops sown at the conclusion of the pasture trial.

Discussion

Weather

From a comparison of the climatological data in Table I with that presented in the previous paper, the marked differences between the climatic conditions of Canterbury and those of Palmerston North are clearly seen. This difference is one both of rainfall and temperature, Canterbury having wider extremes of temperature, being much drier and subject to frequent desicatting Fohn winds. As will be seen, this climatic difference from Palmerston North has been a major factor affecting the total yields, due largely to the relatively strong growth of red clover under these dry conditions. The main feature of the climate during the actual trial period, however, has very obviously been that it was better for the pasture period 1945-48, and poorer than the average for the period subsequent to the pasture trial and in which the wheat crops were grown.

Annual and Seasonal Yields

In comparison with the Palmerston North trial, the outstanding feature of this experiment was the small difference in total annual yields between the main groups. Between the fertilizer treatments there was a consistent yield increase in both groups parallel with the increase in fertilizer, except that there were greater relative increases in the N.R. series. This would be expected when the amount of calcium and phosphorus returned in the dung on the F.R. group is considered[2]. In spite of the few inconsistencies of the

total yields within groups and between years, the main results of the trial were a definite response in both main series to the lime and superphosphate, and the similarity in total yields of the two main groups.

There was relatively little annual variation in yield over the whole series of fertilizer treatments. This is undoubtedly a direct result of the uniformly favourable weather over the trial period, and it may be concluded that the average annual yield of 9,600 lb D.M. recorded is probably an upper limit of pasture production in that district. This figure should be compared with the total annual yield figure of approximately 14,000 lb D.M. secured in the Palmerston North trial.

The differences in seasonal yields between Lincoln and Palmerston North can be seen by comparing Table III with the corresponding tables in the previous paper. In the N.R. treatment at Lincoln, winter growth provided 1 per cent, and summer growth over 50 per cent of the annual yield; in the F.R. treatment, the winter growth provided 6 per cent of the annual yield, while 46 per cent occurred in the spring and 38 per cent in the summer. These figures should be compared with the Palmerston North results where the extremes of growth occur in winter and summer in both the F.R. and N.R. groups. Also, at Palmerston North the differences between the extremes of low and high yields within the annual cycle were not so great (F.R., 12.3 to 33.4 per cent; N.R., 8.9 to 37.8 per cent).

Botannical Composition

The seasonal change in the growth of different species is well demonstrated in the section of Table III showing the botanical constituents. There was a much earlier growth of the grasses, especially the ryegrass, than of the clovers. This position was reversed in the summer period when the ryegrass growth declined, its place being taken by the clovers. The growth of red clover is confined almost wholly to the summer period with only a very small proportion of its total annual production occurring in any other season.

The effects of fertilizers and of dung and urine respectively, are clearly demonstrated in Tabes III, IV and V. The return of dung and urine resulted in very much greater growth of the grasses and the relative suppression of growth of the clovers, especially red clover. On the other hand, the superphosphate and lime showed their responses in a slightly different manner in the two groups. In the N.R. group the increase in the early years was the result of a much greater annual yield of red clover; towards the end of the trial the response was almost wholly due to greater grass yield which made up for the later reduction in red clover growth.

Field observations showed that in the control paddock the grass species other than ryegrass were mainly low growing browntop and Chewings fescue, whereas on the fertilized paddock the main grass constituent other than ryegrass was cocksfoot. White clover showed a small but consistent response to the fertilizer application.

TABLE III. SEASONAL DRY MATTER PRODUCTION AND VARIATIONS IN BOTANICAL COMPOSITION

(Mean Seasonal yields for final three years of trial period for extremes of fertiliser sub-treatments.)

6

Main Treatment	Fertilizer Treatment	Season	% of Annual D. M. Production	Contribution of species as % of seasonal production			
				Ryegrass	Other grasses	White Clover	Red Clover
No return of Dung and Urine	No Fertilizer	Spring	36	39	8	24	30
		Summer	53	7	6	9	77
		Autumn	10	32	14	8	46
		Winter	1	72	15	5	8
	3 cwt Super + 7½ cwt Lime annually	Spring	42	49	4	23	24
		Summer	48	12	5	6	77
		Autumn	9	46	5	8	41
		Winter	1	81	8	7	4
Full return of Dung and Urine	No Fertilizer	Spring	48	67	14	11	8
		Summer	38	25	22	11	43
		Autumn	9	61	20	5	14
		Winter	5	80	13	5	2
	3 cwt Super + 7½ cwt Lime annually	Spring	45	77	11	9	3
		Summer	37	42	16	11	31
		Autumn	12	70	12	5	13
		Winter	6	87	7	5	1

TABLE IV. YIELDS OF DRY MATTER, AND BOTANICAL AND CHEMICAL CONSTITUENTS

Treatments	Period	Total Dry Matter Yield (lb per Acre)	Yield of Species (lb per acre)					Chemical components of herbage (lb per acre)				
			Ryegrass	Other Grasses	White Clover	Red Clover	Other Species	Crude Protein	Soluble Ash	CaO	P_2O_5	K_2O
(a) No return of dung and urine												
No added Fertiliser	May 1944 - 9. 1.45	4400	2673	14	746	615	352	795	354	44	37	152
	10. 1.45 - 15. 1.46	8400	1463	587	2264	3952	134	1813	657	116	67	232
	16. 1.46 - 23. 1.47	6400	1286	616	349	4147	2	1499	520	80	55	183
	24. 1.47 - 23. 1.48	7900	2120	448	1123	4209	tr	1682	624	110	63	213
	Total 1945-48	22700	4869	1651	3736	12308	136	4994	1801	315	185	628
	Average per year	7566	1623	550	1245	4103	45	1665	600	105	62	209
+ 3 cwt Super	May 1944 - 9. 1.45	5400	3389	10	783	829	389	1030	468	76	43	189
+ 7½ " Lime	10. 1.45 - 15. 1.46	12500	2725	232	2393	7150	tr	2772	1143	205	105	410
	16. 1.46 - 23. 1.47	8400	2639	818	422	4521	tr	1993	699	118	80	237
	24. 1.47 - 23. 1.48	7700	3071	225	1431	2973	tr	1656	645	108	69	208
	Total 1945-48	28600	8435	1275	4246	14644	tr	6421	2487	431	254	885
	Average per year	9533	2812	425	1415	4881		2140	829	144	85	285
Weighted Average of the above two treatments	May 1944 - 9. 1.45	4900	3031	12	764	722	371	913	411	60	40	170
	10. 1.45 - 15. 1.46	10450	2094	409	2328	5551	68	2292	900	160	86	321
	16. 1.46 - 23. 1.47	7400	1962	717	386	4334	1	1746	609	103	67	210
	24. 1.47 - 23. 1.48	7800	2596	336	1277	3591	tr	1669	634	109	66	210
	Total 1945-48	25650	6652	1462	3991	13476	69	5707	2143	372	219	741
	Average per year	8550	2217	488	1330	4492	23	1902	714	124	73	247

(b) Full return of dung and urine												
No added Fertiliser	May 1944 - 9. 1.45	5500	4147	104	560	319	370	943	455	51	46	202
	10. 1.45 - 15. 1.46	7700	3716	702	1376	1855	51	1462	633	86	60	253
	16. 1.46 - 23. 1.47	8500	3933	1755	413	2383	16	2059	731	67	85	334
	24. 1.47 - 23. 1.48	7700	4536	1512	876	776	tr	1764	655	69	69	277
	Total 1945-48	23900	12185	3969	2665	5014	67	5285	2019	222	214	864
	Average per year	7966	4062	1323	888	1671	22	1762	673	74	71	288
+ 3 cwt Super + 7½ " Lime	May 1944 - 9. 1.45	6400	3836	33	1223	954	354	1163	568	69	40	263
	10. 1.45 - 15. 1.46	11000	8153	560	1227	1060	tr	2016	954	119	83	419
	16. 1.46 - 23. 1.47	9000	5296	1456	618	1630	tr	2012	775	90	89	352
	24. 1.47 - 23. 1.48	8900	5153	1148	1019	1380	tr	1896	765	89	80	329
	Total 1945-48	28900	18602	3364	2864	4070		5924	2494	298	252	1100
	Average per year	9633	6201	1121	955	1356		1975	831	99	84	367
Weighted Average of the above two treatments	May 1944 - 9. 1.45	5950	3992	68	892	637	362	1053	514	60	43	232
	10. 1.45 - 15. 1.46	9350	5934	631	1302	1458	26	1739	793	103	71	336
	16. 1.46 - 23. 1.47	8750	4619	1606	516	2006	8	2035	753	78	87	343
	24. 1.47 - 23. 1.48	8300	4844	1430	947	1078	tr	1830	710	84	74	303
	Total 1945-48	26400	15393	3666	2764	4542	34	5604	2256	265	232	982
	Average per year	8800	5131	1222	922	1514	11	1868	752	88	77	327

TABLE V. RELATIVE DRY MATTER YIELDS AND BOTANICAL AND CHEMICAL CONSTITUENTS OF HERBAGE

Treatment	Period	Relative Dry Matter Av.NR = 100	Botanical Composition (% of DM)							Chemical Composition (% of DM)				
			Ryegrass	Other Grasses	White Clover	Red Clover	Other Species	Ratio of Grasses to Clovers		Crude Protein	Soluble Ash	CaO	P_2O_5	K_2O
(a) No return of dung and urine														
No added fertiliser	May 1944 - 9. 1.45	58	61	Tr	17	14	8	61	31	18.1	8.1	1.0	0.8	3.5
	10. 1.45 - 15. 1.46	111	7	7	27	47	2	24	74	21.6	7.8	1.4	0.8	2.8
	16. 1.46 - 23. 1.47	85	20	10	5	65	Tr	30	70	23.4	8.1	1.4	0.9	2.9
	24. 1.47 - 23. 1.48	104	27	6	14	53	"	33	67	21.3	7.9	1.4	0.8	2.7
	Average per year	100	21.4	7.3	16.4	54.4	0.5	28.7	70.8	21.7	7.8	1.4	0.8	2.7
3 cwt Super + 7½" Lime	May 1944 - 9. 1.45	71	63	Tr	15	15	7	63	30	19.1	8.7	1.4	0.8	3.5
	10. 1.45 - 15. 1.46	165	22	2	19	57	Tr	24	76	22.2	9.1	1.6	0.8	3.3
	16. 1.46 - 23. 1.47	111	31	10	5	54	"	41	59	23.7	8.3	1.4	0.9	2.8
	24. 1.47 - 23. 1.48	102	40	3	18	39	"	43	57	21.5	8.2	1.4	0.9	2.7
	Average per year	126	29.5	4.5	14.8	51.2	Tr	34.0	66.0	22.4	8.7	1.5	0.9	3.0
Weighted Average of the above two treatments	May 1944 - 9. 1.45	65	62	Tr	16	14	8	62	30	18.6	8.4	1.2	0.8	3.5
	10. 1.45 - 15. 1.46	138	20	4	22	53	7	24	75	21.9	8.6	1.5	0.8	3.1
	16. 1.46 - 23. 1.47	98	26	10	5	59	Tr	36	64	23.6	8.2	1.4	0.9	2.8
	24. 1.47 - 23. 1.48	103	33	4	16	47	Tr	37	63	21.4	8.1	1.4	0.8	2.7
	Average per year	113	25.9	5.7	15.6	52.5	0.3	31.6	68.1	22.2	8.4	1.5	0.9	2.9

(b) Full return of dung and urine															
No added fertiliser	May 1944 – 9. 1.45	73	75	2	10	6	7	77	16	17.1	8.3	0.9	0.8	3.7
	10. 1.45 – 15. 1.46	102	48	9	18	24	1	57	42	19.0	8.2	1.1	0.8	3.3
	16. 1.46 – 23. 1.47	112	46	21	5	28	Tr	67	33	24.2	8.6	0.8	1.0	3.9
	24. 1.47 – 23. 1.48	102	59	20	11	10	"	79	21	22.9	8.5	0.9	0.9	3.6
	Average per year	105	51.0	16.6	11.1	21.0	0.3	67.6	32.1	22.1	8.5	0.9	0.9	3.6
3 cwt Super + 7½ Lime	May 1944 – 9. 1.45	85	59	1	19	15	6	60	34	18.1	8.9	1.1	0.6	4.1
	10. 1.45 – 15. 1.46	147	74	5	11	10	Tr	79	21	18.3	8.7	1.1	0.8	3.8
	16. 1.46 – 23. 1.47	119	59	16	7	18	"	75	25	22.3	8.6	1.0	1.0	3.9
	24. 1.47 – 23. 1.48	117	58	15	11	16	"	73	26	21.3	8.6	1.0	0.9	3.7
	Average per year	127	64.4	11.6	9.9	14.1	Tr	76.0	24.0	20.5	8.6	1.0	0.9	3.8
Weighted Average of the above two treatments	May 1944 – 9. 1.45	79	67	1	15.0	11	6	68	26	17.7	8.7	1.0	0.7	3.9
	10. 1.45 – 15. 1.46	123	6	7	14	15	Tr	71	29	18.6	8.5	1.1	0.8	3.6
	16. 1.46 – 23. 1.47	116	53	18	6	23	Tr	71	29	23.2	8.6	0.9	1.0	3.9
	24. 1.47 – 23. 1.48	111	58	17	11	14	Tr	75	25	22.1	8.6	1.0	0.9	3.7
	Average per year	116	58.3	13.9	10.5	17.2	0.1	72.2	27.7	21.2	8.6	1.0	0.9	3.7

In the F.R. group, the response to fertilizer was mainly in terms or ryegrass but with some increase in the growth of white clover. There was a marked reduction in red clover, cocksfoot, browntop and flat weeds. This position obtained throughout the trial, except that in the final summer there was again an increase in red clover growth on the fertilized treatments.

Table V shows clearly the large differences in botanical composition induced by returning or withholding dung and urine, the outstanding feature being the variation in the grass-to-clover ratio. Herbage from the N.R. group consisted of approximately 32 per cent grasses and 68 per cent clovers, whilst in the F.R. group this changed to 72 per cent grasses and 28 per cent clovers. Fertilizer and lime increased the ryegrass percentage in both groups and induced a decrease in clover percentage. It is of interest to compare the botanical composition of the lowest yield treatment (N.R. no fertilizer) with that of the highest (F.R. high fertilizer). The former was dominated by red clover, and only 28 per cent of the herbage production was contributed by the grasses, the latter had an average grass-to-clover ratio of 76 to 24, with red clover contributing only about half of the total clover growth. This difference in botanical composition is the obvious explanation of the difference in seasonal growth. Where grass was dominant, the greatest growth occurred in spring; where red clover was dominant, the greatest growth was in summer.

Chemical Composition

The changes in botanical composition induced by the various treatments probably accounts in part for the observed variation in chemical composition. Thus, the higher percentage of calcium in the N.R. group is almost certainly due to its higher clover content. On the other hand, the increase in potash level in the F.R. group as compared with N.R. group is probably due largely to the high content of potash in the urine, although some slight increase might be expected from the higher proportion of grass in the pasture[8].

TABLE VI. WHEAT YIELDS

Previous Treatment	1948-49			1949-50		
	Grain + Straw Relative Yields	Grain		Grain + Straw Relative Yields	Grain	
		Lb per acre	Relative Yields		Lb per acre	Relative Yields
No Return of Dung and Urine						
No Fertiliser	100	2,554	100	100	2,274	100
1 cwt Super + 2½ cwt Lime	103	2,767	108	106	2,637	116
2 " " + 5 " "	106	2,843	110	99	2,449	107
3 " " + 7½ " "	115	2,758	108	96	2,307	101
Full Return of Dung and Urine						
No Fertiliser	110	2,536	99	106	2,297	101
1 cwt Super + 2½ cwt Lime	114	2,902	113	106	2,554	112
2 " " + 5 " "	111	2,755	108	107	2,541	110
3 " " + 7½ " "	107	2,621	102	96	2,291	101

Wheat Yields

In Table VI are given the yields of the wheat crops taken in the two years following the conclusion of the pasture trial. Throughout the growth period in both years no visible difference was apparent, and no significant differences in yield resulted. There

was also no difference in yields of straw as measured by weighing sheaves from each paddock. As already mentioned, the weather conditions over the two seasons during which the wheat was grown were very much drier than during the four years of the pasture trial. The autumn of 1948 was extremely dry, and for the next two years rainfall was considerably below average, the annual precipitation being 20.06 in. and 18.44 in. respectively, as compared with the average of 25 to 28 in. In addition, there was a much higher mean wind force and also a higher evaporation rate than is generally experienced[9].

The lack of any difference in the yields of the wheat crops may have been due to the dry weather conditions over the 2-year period. If the amount of available water limited the yield, this would have masked the effect of other soil fertility factors. On the other hand, the results are in accord with those of the recent Woburn trial[10] where the residual fertility after three years of cut lucerne was the same as after a 3-year grazed pasture. All that can be taken from the results is a suggestion of a better appreciation of the need for trials fully replicated over many seasons to secure any real measure of residual fertility. The data are presented largely because of the almost complete lack of New Zealand experimental work on this aspect of pasture production.

General

In addition to the specific comments relating to the Tables there are also some general points which are worthy of further discussion. Firstly, in considering total herbage yields it must again be emphasized that the weather conditions were unusually favourable for growth. As an instance of the annual variability of Canterbury pasture growth, the average yields of 9,600 lb D.M. per acre in this trial should be compared with yields from camparable trials at Lincoln which showed yields of only 4,000 lb D.M. per acre in 1948[11]. It is probable that the N.R. group would have outyielded the F.R. group under these latter circumstances, due to the greater ability of red clover to withstand drought. Moreover, in a drier period it is probable that the fertilizer responses would have been much lower than those secured in this trial.

The progressive increases secured from the increasing application of fertilizer, contrast sharply with the accepted practice in Canterbury, where 1 cwt of superphosphate is regarded as the maximum profitable application, irrespective of soil type or soil fertility. Such practices have, however, developed as a result of the use of poorer species and strains of grasses and of the variability of annual rainfall[12]. It is worthy of repetition that in this trial the annual application of 3 cwt superphosphate plus 7½ cwt of lime has resulted in a consistent annual increase of nearly 2,000 lb D.M.—approximately the feed supply of two extra sheep per acre.

Total yields at Palmerston North were much higher than at Lincoln, those of the F.R. group being 14,000 lb D.M. at Palmerston North and 9,600 lb D.M. at Lincoln, and those of the N.R. group being 11,000 lb D.M. at Palmerston North and 9,500 lb D.M.

at Lincoln. There was also a much greater seasonal variation in growth at Lincoln than at Palmerston North and peak periods were different. On the other hand, there was relatively little difference in botanical and chemical composition between the F.R. groups at the two centres, the only outstanding difference being the relative positions of the two clover species. At Palmerston North, the average contribution of white clover and red clover to the annual yields were 22.7 per cent and 2.9 per cent respectively, and at Lincoln, 9.9 per cent and 14.1 per cent respectively. At Palmerston North, there was a marked decline in red clover over the trial period, but at Lincoln this species consistently contributed about 14 per cent of the annual yield. Ryegrass and other grasses were greater in production at Palmerston North than at Lincoln, again probably due to the better climate and to the extra nitrogen made availiable by the greater growth of white clover at Palmerston North. There were slight differences in favour of Palmerston North in the leaf levels of nitrogen, phosphate and potash, but no difference in calcium.

It is of interest to consider the uptake of nutrients by the pasture plants and the consequent loss from the soil in the N.R. group. The average annual drain in terms of commercial fertilizers in the non-fertilized treatments were as follows:—

Nitrogen equivalent to		11.6	cwt	of Sulphate of ammonia
Calcium	„ „	1.7	„	„ Carbonate of lime
Potassium	„ „	6.2	„	„ 30 per cent potash salts
Phosphorus	„ „	2.7	„	„ Superphosphate (20 per cent)

In the fertilized N.R. group, the fertilizer equivalents are 14.8, 2.3, 8.5, and 3.7 cwt respectively. Thus, it is seen that the extra nutrient drain was balanced by the fertilizers applied, except in the case of potash.

In the F.R. series, the slight difference in herbage composition produced a different annual turnover of nutrients through the plant-animal cycle. The assumption is made that in this trial there was very little retention of minerals or nitrogen by the mature wethers used in all grazing. The average annual turnover in terms of commercial fertilizers for the non-fertilized treatment of the F.R. group was as follows:—

Nitrogen equivalent to		12.2	cwt	of Sulphate of ammonia
Calcium	„ „	1.2	„	„ Carbonate of lime
Potassium	„ „	8.6	„	„ 30 per cent potash salts
Phosphorus	„ „	3.1	„	„ Superphosphate (20 per cent)

In the fertilized F.R. group, the fertilizer equivalents of the turnover are 13.7, 1.6, 10.9 and 3.6 cwt respectively.

Considering these annual uptake figures against the annual fertilizer application, it will be seen that the immediate recovery of the added phosphate has been of the order of 30 per cent in the N.R. series, and under 20 per cent in the F.R. series. The difference between the unfertilized treatments in the two main groups can be taken as an indication of phosphate value of the dung normally returned by the grazing animal. The high nitrogen yields in all series are a good indication of the nitrogen fixation by the clovers.

Other trials in progress at Lincoln[13] have demonstrated how low is the nitrogen supply from other sources, and how essential is the legume in the rotation. However, the point of practical interest is the rise in the uptake of nitrogen and potash in both series where phosphate and lime are added. The high potash figures shown by the analyses are undoubtedly a reflection of the general high level in the soil used for the experiment.

The excellent summer and total annual yields of the N.R. series as a whole offer a useful suggestion for practical application to Canterbury farming practice. Summer production is of the utmost importance for lamb fattening in Canterbury. From the results of this trial it would appear that a pasture managed to give high red-clover production in the summer would do much to provide food for the difficult drought periods. It would have the advantage over rape in that it lasts more than one season, and over lucerne in that it provides better grazing. In addition, the other constituents of the pasture would provide fodder for the other periods of the year; for instance, with short rotation ryegrass and white clover in the mixture, winter and spring production would be considerable, while the red clover would fill the summer gap. Besides saving the cultivation costs which are incurred with the annual type of fodder crop such as rape, the use of red clover in such a special purpose pasture would probably lead to a greater rise in soil fertility, and thus increase yields of other crops in the rotation. It is apparent, however, that special grazing practices and suitable seasonal spelling will be necessary in order to secure the greatest value from the red clover in such special purpose mixtures. Trials on this aspect are at present under way at Lincoln[14].

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REFERENCES

1 SEARS, P. D. and NEWBOLD, R. P. 1942: *N.Z. J. Sci. Tech. 24*: 36A-61A.
2 SEARS, P. D., GOODALL, V. C. and NEWBOLD, R. P. 1948: *N.Z. J. Sci. Tech. A. 30*: 231-49.
3 SEARS, P. D. 1949: *Proc. N.Z. Sheepbreeders' Assoc. Massey Agric. Coll. N.Z.* p. 103.
4 SOIL BUREAU, N.Z. Dep. Sci. Ind. Res. Private Communication.
5 SEARS, P. D. 1951: *N.Z. J. Sci. Tech. A33*(1): 1-29.
6 SEARS, P. D. and GOODALL, V. C. 1942: *N.Z. J. Sci. Tech. 23*: 301A-304A.
7 CALDER, J. W. 1948: *Canterbury Agric. Coll. Ann. Rep.*, p. 35.
8 SEARS, P. D. Unpublished data.
9 Canterbury Agricultural College Ann. Rep. 1948-1951.
10 WHYTE, R. O. and JACKS, G. V. ED. 1944: Imp. Agric. Bur. Joint Publ. No. 6, p. 49.
11 CORKILL, L., 1949: *Emp. J. Exp. Agric. 17*: 157-69.
12 CONNELL, R. P. 1948: *Proc. N.Z. Grasslands Assoc.*, p. 27.
13 THURSTON, W. G. 1949: *N.Z. Dep. Sci. Ind. Res. Agron. Rev.* No. 4.
14 *N.Z. Dep. Sci. Ind. Res. Ann. Rep.* (Grasslands Div.) 1950, p. 55.

TWO VIRUS DISEASES OF GLADIOLUS

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Summary

Evidence is presented to show that a legume virus which is widespread in gladioli in New Zealand, is the same as that occurring in the United States of America. The virus recovered from New Zealand grown gladioli is identified as pea-mosaic virus. Cucumber-mosaic virus was recorded from gladioli showing white blotching of flower colour. White blotching was reproduced by artificial inoculation.

Introduction

Since Dodsall (1927) recorded a virus disease of gladioli, many reports of the diseases, mild mosaic and white break, have appeared. Only relatively recently, however, have the causative viruses been identified. McWhorter *et al.* (1947) recovered from mild mosaic gladioli a virus which they identified as bean yellow-mosaic virus. Cucumber-mosaic virus was recovered from gladioli showing white blotching of flower colour by both White (1946) and Bridgman (1951).

Surveys carried out in the 1949-50 season showed that symptoms typical of mild mosiac were widespread among gladioli in New Zealand, while white blotching of flowers was of more restricted occurrence. This paper records the indentification of the two viruses occurring in New Zealand grown gladioli as pea-mosaic and cucumber-mosaic viruses.

Pea-mosaic Virus

Symptoms

Leaves of gladioli from which pea-mosaic virus has been recovered may be symptomless or show a pale green or yellowish mottling between the veins (Fig 1). In severe cases, the yellowing may involve large areas, giving the leaves a streaked appearance. Flower colour of infected plants is often broken by dark stripes parallel to the veins (Fig. 2). In white, cream or yellow varieties the stripes are usually pink in colour.

Identity

Inoculations of pea (*Pisum sativum* L.) and broadbean (*Vicia faba* L.) plants with sap from infected gladioli resulted in the development of a leaf mottling similar to that produced in these hosts by pea-mosaic virus (Chamberlain, 1936). Symptoms typical of pea-mosaic virus infection also occurred in blue lupin (*Lupinus angustifolius* L.), red clover (*Trifolium pratense* L.) and subterranean clover (*T. subterraneum* L.) when plants were inoculated with sap from broadbeans containing the virus from gladioli. Inoculated French bean (*Phascolus vulgaris* L.) plants of varieties Pencil Pod Wax, Market Wonder, Canadian Wonder, and Stringless Greenpod developed chlorotic spotting and vein yellowing. No infections were obtained in white clover (*T. repens* L.), cucumber (*Cucumus sativus* L.), White Burley tobacco (*Nicotiana tabacum* L.) or *N. glutinosa* Linn.

FIG. 1.—Gladiolus leaves showing range of symptoms on plants infected with pea-mosaic virus. x ⅛.

(*Photo by S. A. Rumsey*)

FIG. 2.—Flowers of Robert Bennett Gladiolus from plant infected with pea-mosaic virus showing dark pencil streaking of flower colour. x ⅛.

(*Photo by S. A. Rumsey*)

Reaction of a selection of pea varieties to inoculation with sap from infected pea plants was the same as that described for pea-mosaic virus by Chamberlain (1939a). Varieties Greenfeast, Greencrop, and Stratagem were susceptible, and William Massey, Lord Chancellor and Hursthouse (Greenfeast Rogue) were immune.

The thermal inactivation point (ten-minute treatment) using broad-bean plants both as source of virus and as test plants was between 62° and 64° C.

From this evidence, the legume virus infecting gladioli in New Zealand is identified as a strain of pea-mosaic virus which is transmissible to French bean.

McWhorter *et al.* (1947) identified a virus attacking gladioli as bean yellow-mosaic virus, which they found to be widespread in gladioli in the United States of America. Inconclusive results were obtained by these authors when French bean plants, variety Blue Lake, were inoculated from gladioli. Infection was transmitted, however, in four out of nine trials using broadbean as the test plant. Grogan and Walker (1948) found that bean yellow-mosaic virus was related to common bean-mosaic virus, and stated that one of McWhorter's gladiolus isolates was different from either of these bean viruses.

From the evidence of Grogan and Walker that the virus from gladioli is distinct from common bean-mosaic and bean yellow-mosaic viruses, and because McWhorter's gladiolus virus was more readily transmissible to broadbean than to French bean, it is highly

probable that legume virus recorded from gladioli in the United States of America is a strain of pea-mosaic virus; also, because gladiolus corms have been freely interchanged between North America and New Zealand, and because symptoms of the American mild mosaic of gladioli are similar to those occurring on infected plants here, it is considered that the causative virus is the same in both countries.

Incidence

Ninety-eight gladiolus plants of 37 varieties collected from several localities during January and February 1950 were tested for infection by inocuation to broadbeans or pea, or both; 64 plants were found to be infected. The proportion of plants infected was approximately the same from each district. Although some of the plants were collected because they showed symptoms, it is apparent that pea-mosaic virus is widespread among gladioli in New Zealand.

Fig. 3.—Flowers of Rosea-gladiolus from plant naturally infected with cucumber-mosaic virus showing white blotching of flower colour. x $\frac{2}{3}$.

(*Photo by S. A. Rumsey*)

Transmission to other crops

In the United States of America high incidence of bean yellow-mosaic has been reported in beans growing adjacent to gladiolus plantings. No similar outbreaks have been observed in New Zealand.

Pea and broadbean crops in home gardens, however, are commonly infected with pea-mosaic. Since two aphid vectors of this virus, *Myzus persicae* Sulz. and *Macrosiphum cuphorbiae* Thomas, frequently infest gladioli, it is probable that these plants are a common source of infection in many districts.

CUCUMBER-MOSAIC VIRUS

Inoculation with sap from gladioli showing white blotching of flower colour (Fig. 3) caused symptoms typical of cucumber virus on cucumber, White Burley tobacco, *N. glutinosa,* celery (*Apium graveolens* L.), spinach (*Spinacea oleracea* L.) and zinnia (*Zinnia elegans* Jacq. var. Lilliput). The identification of this virus as cucumber-mosaic was confirmed by a cross protection test using Price's indicator strain (Price, 1935). Systemic infection with the virus from gladioli significantly reduced the numbers of local lesions produced by Price's strain.

A set of 12 gladioli, variety Picardy, known to be infected with pea-mosaic virus, were treated as follows: Four were inoculated with cucumber-mosaic virus from a gladiolus plant, variety A. W. Jones, four with a stock culture of this virus, and four left uninoculated. All inoculations were shown to be successful by transfer to cucumber, while all check plants remained free of cucumber-mosaic virus. No differences in leaf symptoms were noted. When plants flowered, six of the eight inoculated plants developed severe white flower blotching as well as dark pencil streaking which was the only symptom on flowers of the check plants. Attempts to transmit cucumber-mosaic virus to healthy gladioli have not been possible, owing to the lack of plants known to be free from infection with pea-mosaic virus.

It has been established that infection with cucumber-mosaic virus causes white blotching of flower colour in gladioli; however, since pea-mosaic virus was present in all plants, the above results do not show whether this symptom is caused by the former virus alone or is a product of the mixture of viruses.

Incidence

White blotching of flower colour occurs in gladioli throughout New Zealand. In most localities it is rare, but where there is a high incidence of infection with cucumber-mosaic virus in other crops, this disease of gladioli is more common. In one such district, up to ten per cent infection in commercial plantings, and 90 per cent in home gardens has been observed.

CONTROL MEASURES

Since pea-mosaic virus is almost universally present in existing stocks of gladioli, it is impractical to eradicate the disease from plantings of established varieties. New varieties could be kept healthy if raised in isolation from existing stocks and other sources of infection such as red and subterranean clovers, peas, broadbeans and blue lupins.

Incidence of cucumber-mosaic virus is still low enough for further spread to be limited by destruction of infected plants as soon as symptoms are observed, provided that alternative centres of infection are not present.

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References

Bridgman, G. H., 1951: Abstr. in *Phytopath. 41*: 5.

Chamberlain, E. E. 1936: *N.Z. J. Sci. Tech. 18*: 544-56.

———— 1939a: *Ibid. 21*: 178A-83A.

———— 1939b: *Ibid. 21*: 73A-90A.

Dodsall, L. 1928: *Phytopath. 18*: 215-7.

Grogan, R. G. and Walker, J. C. 1948: *J. Agric. Res. 77*: 301-14.

McWhorter, F. P., Boyle, L. and Dana, B. F., 1947. *Science, 105*: 177.

Price, W. C. 1935: *Phytopath, 25*: 776.

White, N. H. 1946: Plant Disease Survey of Tasmania for Three Years 1943-4-5, *Tas. Dept. Agric. Rep.* (mimeographed). 30 pp.

CONTROL OF SOFT-ROT (*Erwinia carotovora* (Jones) Holland) IN CARROTS DURING TRANSIT AND IN STORAGE

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Summary

A highly significant reduction in soft-rot infection of artificially inoculated carrots resulted from post-harvest treatment with:

Bordeux 6-8-100 and 12-16-100; Cuprox at 3 lb and 5 lb in 100 gal water; Copper Sandoz at 2½ lb and 5 lb in 100 gal water; Perenox at 5 lb in 100 gal water; and also by exposure to bright sunshine.

Significant reduction in infection was brought about by Copper zeolite at 5 lb and 12 lb in 100 gal water.

Phygon, 1 lb and 2 lb in 100 gal water, Arathane, 2 lb in 100 gal water, Venturicide, 2 lb in 100 gal water, and water were not effective.

Introduction

Extensive losses are caused by bacterial soft-rot (*Erwinia carotovora* (Jones) Holland) in vegetables during transit and in store. Vegetables form an excellent medium for the growth of bacteria, but for development these organisms must have access to the internal tissues and have suitable incubation conditions. Wounds inevitably occur at harvesting and during transport to market. Conditions of high temperature and humidity regularly develop in confined spaces and promote development of this disease. Refrigeration can greatly reduce spoilage of produce, but in New Zealand there is no general provision for refrigeration during transit or in store. Experiments have been carried out with various compounds to test the value of post-harvest treatment of carrots as a means of reducing losses from soft-rot.

Experimental Methods

Fresh disease-free carrots, 3-6 in. long, were damaged by scraping and bruising with a knife, so that the epidermis and several underlying cell layers were removed or broken. The carrots were then immersed for two minutes in woter heavily inoculated with a virulent strain of *Erwinia carotovora*. Microscopical examinations and moist-chamber determinations showed that the inoculum contained large numbers of soft-rot organisms. After draining for two to three hours, without drying, samples of 50 carrots were treated in one or other of the ways listed below. Where liquid treatments were given, the samples were immersed and agitated for four minutes. Fifty inoculated carrots were retained as checks without further treatment.

Experiment I. 29 June 1949

(1) Bordeaux mixture (a solution of copper sulphate, hydrated lime and water, 6-8-100 and 12-16-100;

(2) Cuprox, a proprietary copper oxychloride containing 50 per cent copper, 3 lb and 5 lb in 100 gal water;

(3) Copper Sandoz, a proprietry cuprous oxide containing 50 per cent copper, 2½ lb and 5 lb in 100 gal water;

(4) Phygon, a proprietary mixture containing 85 per cent dichloronaphthoquinone, 1 lb and 2 lb in 100 gal water.

Experiment II. 15 September 1949

(1) Cuprox, 5 lb in 100 gal water;
(2) Copper Sandoz, 5 lb in 100 gal water;
(3) Perenox, a proprietary cuprous oxide containing 50 per cent copper, 5 lb in 100 gal water;
(4) Copper zeolite* containing 20 per cent copper, 5 lb in 100 gal water; ;
(5) Phygon, 2 lb in 100 gal water;
(6) Arathane, a proprietary compound containing 25 per cent dinitro-carpryl-phenyl-crotonate, 2 lb in 100 gal water;
(7) Venturicide, a proprietary mixture containg 2½ per cent phenyl mercury chloride, 2 lb in 100 gal water;
(8) Water.

Experiment III. 3 April 1950

(1) Bordaux, 6-8-100;
(2) Cuprox, 5 lb in 100 gal water;
(3) Perenox, 5 lb in 100 gal water;
(4) Copper zeolit, 5 lb and 12 lb in 100 gal water;
(5) Dried thoroughly in bright sunshine for twenty minutes, roots turned once in this period;
(6) Water.

TABLE I. PERCENTAGES OF EDIBLE CARROTS AFTER TREATMENT FOLLOWING INOCULATION WITH SOFT-ROT ORGANISMS

Treatment	Concentration of Compound in 100 gal. water (lb)	Percentage of Edible Carrots		
		Expt. I after 14 days	Expt. II after 14 days	Expt. III after 21 days
Bordeaux 6-8-100	6 - 8	89 **	-	96 **
12-16-100	12 - 16	87 **	-	-
Cuprox	3	94 **	-	-
	5	97 **	81 **	89 **
Copper Sandoz	2½	86 **	-	-
	5	88 **	86 **	-
Perenox	5	-	92 **	95 **
Copper zeolite	5	-	82 **	85 *
	2	-	-	86 *
Phygon	1	31	-	-
	2	35	47	-
Arathane	2	-	70	-
Venturicide	2	-	52	-
Sun dried		-	-	90 **
Water		-	58	72
Inoculated only		43	57	71
Differences necessary for significance at	5 %	19.9	15.3	12.8
	1 %	26.6	20.2	16.9

** Highly significant compared with "Inoculated only"
* Significant compared with "Inoculated only"

Immediately after treatment, the corrots were divided into five replications of ten each and wrapped in damp jute squares. These bags were kept moist at tempertures between 63° and 80°F. for fourteen days in Exp. I and II, and between 55° and 65°F. for twenty-one days in Exp. III. Records were taken of severely rotted (not edible), slightly rotted, and clean carrots. For statistical purposes slightly rotted carrots were counted as half edible. Records were also taken of the effects of treatment on the appearance of the roots. At the conclusion of each experiment the edible carrots were eaten to determine whether any tainting had occurred. For this test the carrots were scraped and cooked in the normal way.

RESULTS

The percentages of edible carrots in the three experiments are shown in Table I.

Phygon, Arathane, Venturicide, sun-dried and water treatments caused no effect on the appearance of the carrots. Perenox and Copper Sandoz caused a barely noticeable light brown deposit on the roots. Bordeaux, Cuprox, and copper zeolite left a noticeable blue or green deposit which could not be regarded as seriously affecting appearance for market.

No treatment gave any detectable taint to cooked roots.

DISCUSSION

All the solutions containing copper were efficient in protecting carrots from soft-rot in the presence of large numbers of these bacteria, under conditions of temperature and humidity favourable for their development. Exposure to bright sunshine for twenty minutes sufficient to dry the carrots thoroughly (Exp.III) also gave efficient protection from soft-rot. The practicability of this method, however, would depend in the weather and on the amount of surface moisture at time of harvest. For it to be efficient the carrots would have to be turned to allow all-over sun drying.

Since dipping in water did not reduce infection, the control by copper solutions was not due to dilution of inoculum. The higher percentage of edible carrots in the untreated section of Exp. III may be accounted for by the fact that in this experiment temperatures of storage were considerably lower and retarded development of the soft-rot organisms. A comparison of results from materials used at two concentrations, e.g., Bordeaux and Cuprox, shows that there was little difference between the two concentrations. It is possible that even lower concentrations would suffice.

It is recommended that when soft-rot infection is expected, particularly in heavily infected areas during wet or humid weather, post-harvest chemical treatments should be applied for control during transit and in store. It is suggested that bagged carrots be dipped in one of the copper solutions at the lower concentrations tested. The choice of a material would be governed by availability, cost, and extent of possible surface deposit.

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* Supplied by Mr. W. Fyfe, Chemistry Dept., University of Otago.

RESISTANCE OF LINSEED AND LINEN-FLAX VARIETIES TO FLAX-RUST (Melampsora Lini) IN NEW ZEALAND. III

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(*Received for publication, 20 August, 1952*)

Summary

Sixty-nine varieties of Linseed and Linen-flax were tested for resistance to all but Race 5 of the 12 New Zealand races of *M. lini*. Six were highly resistant and 10 resistant to all races. The remaining 53 showed various degrees of susceptibility.

A logarithmic transformation was applied to the trial total uredosorus counts of each variety. It was found on analysis that there were no significant gaps in the equivalent series of variety means. Individual means could be compared by a ratio test.

Introduction

Subsequent to investigations on varietal resistance of Linseed and Linen-Flax to Flax-Rust (*Melampsora lini* (Ehrenb.) Lev.) (Cruickshank, 1950, 1951) physiologic races of rust have been studied and new varieties of Linseed and Linen-Flax introduced as potential rust-resistant breeding material. In this paper an account is given of glass-house trials comparing the rust resistance of these new varieties, those grown commercially, and the most important varieties and numbered lines in the collection of the Crop Research Division.

Experimental Methods

Sixty-nine varieties of Linseed and Linen-flax were tested in three groups. With the exception of Golden Viking, which was included in all trials as a standard, each variety was tested in three trials. For each trial, three pots of 20 plants of each variety were grown. Inoculations were made, and the relative resistance of varieties was determined, using the methods described by Cruickshank (1950). The inoculum used was a mixture of the New Zealand Races 1-12 (except 5) as identified and described by Cruickshank (1952).

Results

It was clear from the pot total uredosorus counts that variety-trial interaction was very much greater than pot-to-pot variation and should therefore be used for error estimates. Accordingly, only the total counts for each variety in each trial were analysed, adjusted to equal numbers of leaves and transformed to log $(1 + x)$. This transformation made the variability of the counts over the range of susceptibility more nearly equal, though it was too powerful for the most resistant varieties. In the original data the means of the sixteen most resistant varieties occupied only one-seventeenth of the total range of means; in the transformed data they covered half the total range.

The three groups of varieties were first analysed separately. Variety differences were highly significant in each group, and the three error mean squares, being almost equal, were pooled for testing individual variety differences. Classification on susceptibility is simplest if the varieties fall into distinct groups; otherwise, it must be arbitrary. When

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TABLE I.. VARIETAL SUSCEPTIBILITY OF LINSEED AND LINEN FLAX TO FLAX-RUST *

Variety	C.I. No. **	Variety Grand Mean ***	General Grading
I.F. 22450/30	-	0.00	
Morye	112	0.00	
Argentine Seln.	462	0.04	Highly
United States Rio	280	0.33	resistant
Russian x Argentine Seln.	896	0.35	
I.F. 812	-	0.35	
Tammes Pale Blue	333-1	3.8	
Redwood	1130	4.3	
B.5126	-	4.8	
New Zealand Rio Seln.	-	13	
Moose x N.D. 127	-	13	Resistant
Uruguay F.79	-	14	
B.5128	-	15	
Rocket	1133	15	
Uruguay F.77	-	16	
Daenfeldt	-	18	
Malabrigo	696	33	
Plate	-	35	
Uruguay F.78	-	36	
F.146	-	46	
Sheyenne	1073	53	
I.F. 808	-	58	
Koto	842	60	
Moose 12/28	-	63	
Calar	-	69	
Maramko	-	69	
806/3	-	73	
Wada	-	75	
Stakhanovetz	-	76	
Korrick III	-	78	
Diadem	321	78	
Hindi	-	79	
F.145	-	80	Susceptible
Argentine II	-	82	
D-83	-	82	
Cascade	-	89	
Crystal	982	89	
Sagenan x Bombay	671	101	
Moose 11/29	-	102	
Pergamino	882	112	
Ottawa 770 B	355	112	
Moose 11/28	-	118	
F.149	-	126	
F.83	-	138	
Beladi	-	139	
Renew	839	149	
Marroca L.N.24	-	160	
Golden Viking	-	170	
Concurrent	801	176	
F.93	-	177	
Kharamabad	-	180	
Custer	1083	192	
North Dakota 73	-	209	
Korrick II	-	215	
Bison x 479	975	234	
Korrick I	-	234	
Biwing	917	241	
Liral Prince	-	252	
North Dakota 114	13	253	
North Dakota 52	8	255	
Minemi	-	263	
Valuta	-	266	
Sadd's English	-	269	
Vaanila	-	272	
Nansho	-	287	
Liral Crown	882	310	
N.Z. Commercial	-	315	
Sagenan No. 1	207	320	
Redson	970	337	

* To ascertain the significant difference between any two figures add 1.0 to each and find their ratio. A ratio of 3.2 or more indicates a significant difference in susceptibility and 4.7 or more a highly significant difference.

** C.I. No. refers to accession number of the Division of Cereal Crops and Diseases, Department of Agriculture, United States of America.

*** Variety grand mean of uredosorus counts per pot of 20 plants. Each variety tested in three trials.

the variety means were placed in order of resistance, one difference between adjacent varieties, that between I.F. 812 and Tammes Pale Blue, appeared just significant on a *t*-test. This is not a valid test for gaps in a series and, in any case, the overall standard error was too small for comparing the most resistant varieties.

The method of Tukey (1949) for testing the most extreme of a group was applied successively in the whole group of means, using the overall standard error. The sixteen most resistant varieties were all significantly different from the grand mean of the remainder, the normal deviates for the sixteenth and seventeenth, Daenfeldt and Malabrigo, being 3.3 and 1.5 respectively, so that the separation was clear-cut. Within these sixteen, the first six similarly formed a group distinct from the following ten, the normal deviates for I.F. 812 and Tammes Pale Blue being 4.6 and 1.2. Deviations from the group means in these two small groups were not significant, but in the third group were highly significant. It is natural to class the three groups as "highly resistant," "resistant" and "susceptible."

From the variety averages of the transformed data equivalent mean counts per pot of 20 plants were calculated, and these are presented in Table I.

It follows from the transformation that any two figures in this table may be compared by adding 1.0 to each and then finding their ratio. A ratio of 3.2 or more indicates a significant difference in susceptibility, and 4.7 or more, a highly significant difference. For example, the comparison of New Zealand Rio Seln. with United States Rio. $\frac{13 + 1}{0.33 + 1} = 10.5$, shows that there is a highly significant difference in their susceptibility. The above ratios for significance are too small at the "highly resistant" end of the range, and I.F. 812 cannot be claimed to be significantly more resistant than Tammes Pale Blue, although they give a ratio of 3.6. This is not inconsistent with their being placed in different classes.

Conclusions

Although this study does not give information about the reaction of individual rust races on individual varieties, it does in general define resistance of varieties in terms of the races of *M. lini* known in New Zealand. Of the 69 varieties tested for resistance to a mixed inoculum of these races, 6 were classed as highly resistant, 10 were resistant and the remaining 53 showed various degrees of susceptibility.

An important change in varietal resistance since 1949 is due to the occurrence of a new race (N.Z. Race 12) identified first in 1950 and again in 1951. Such varieties as Ottawa 770B, Sheyenne, Stakhanovetz, D-83, 806/3, Wada, Cascade and Argentine II, which were highly resistant in 1949, and Golden Viking, previously graded as resistant, are now classed as susceptible.

References

Cruickshank, I. A. M., 1950: *N.Z. J. Sci. Tech. A31* (6): 54-57.
———, 1951: *Ibid. 33* (2): 62-64.
———, 1952: *Ibid. 34* (2): 128-33.
Tukey, J. W., 1949: *Biometrics, 5*: 99-114.

MANGANESE DEFICIENCY OF APRICOTS

By E. G. Bollard, Fruit Research Station, Department of Scientific and Industrial Research, Auckland

(*Received for publication, 4 December 1952*)

Summary

A chlorosis of apricot foliage occurring in Central Otago has been shown to be due to a deficiency of manganese.

Chlorotic leaves contained only 9.9 p.p.m. of this element in contrast to levels of 86-94 p.p.m. in leaves from healthy trees.

Introduction

In New Zealand deficiency of manganese is known to cause leaf chlorosis in citrus (Taylor and Burns, 1938) and peaches (Atkinson, 1944) particularly on soils with a pH of over 6.0. A leaf chlorosis of apricots growing in Central Otago has now been shown to be due to the same cause.

Symptoms

This disorder appears as a foliar chlorosis. In some leaves only the leaf margins are affected, but in many cases the chlorosis is intervenal, while in severely affected leaves only the veins remain green. (Fig. 1). Symptoms are more pronounced on older leaves than on young ones, and there may be no obvious chlorosis until January. Those leaves on an affected tree that do not show a chlorotic pattern may be a paler green than normal.

Field Trials

Trees from an affected block of apricots, variety Roxburgh Red, growing in a sandy soil of pH 7.3, in the Alexandra district, were selected for test. No symptoms were showing at time of treatment, but trees showing chlorosis had been marked in the previous season.

Each of the following spray mixtures was applied twice to four trees:

(1) 3 lb Manganese sulphate + 4 lb hydrated lime + 50 gal water.

(2) 3 lb Ferric sulphate + 4 lb hydrated lime + 50 gal water.

(3) 3 lb Zinc sulphate + 4 lb hydrated lime + 50 gal water.

The first application was made on 10 November and a second on 15 December, 1951. There were also a number of trees which received no sprays.

By the end of January the chlorosis had appeared in all trees, save those sprayed with manganese. By March, the effect of manganese was even more apparent. No chlorosis could be seen in the trees which had received manganese, whereas marked chlorosis was visible on check trees and trees which had received other treatments. In addition, leaves on manganese treated trees were of a darker green than any on check trees.

Leaf Analysis

Leaves for analysis were selected in each instance from the lower part of current season's growth. Samplings were made from check trees in another part of the Alexandra district and from healthy trees in the Levin district. Manganese determinations were made by Miss T. Marwick, Soil Bureau, Department of Scientific and Industrial Research.

Source of material	Date of sampling	Soil pH	Manganese content (p.p.m. Mn in dry weight)
Chlorotic trees, Alexandra	22/2/52	7.3	9.9
Healthy trees, Alexandra	22/2/52	6.3	86.0
Healthy trees, Levin	10/3/52	5.5-6.0	94.0

ILLUSTRATIONS

FIG. 1.—Apricot leaves, var. Roxburgh Red. Healthy leaf on left. Other leaves showing symptoms of manganese deficiency.
Photo: S. A. Rumsey

RECOMMENDATION

Although two sprays of manganese sulphate were used in the diagnostic experiment, it is probable that one spray at the same strength would be sufficient to remedy the disorder. Two manganese sprays left a black deposit on fruits. With peaches this can be avoided by applying sprays as soon as new shoots have made about an inch of growth, and it is probable that a similar procedure would also be effective with apricots. If lime is not used in the spray, leaf damage may occur.

INCIDENCE

A further instance of this deficiency in Bolton apricots has since been recorded in the Roxburgh district. Manganese deficiency is known in peaches in many parts of the Central Otago fruitgrowing areas, and it is probable that further instances of its presence in apricots will be found.

ACKNOWLEDGMENT

The writer wishes to acknowledge the co-operation of Mr. J. Sanders, Alexandra, who permitted use of his trees. Thanks are due to Mr. W. S. Kemp, Horticulture Division, Department of Agriculture, for assistance with recording, and to Miss T. Marwick, Soil Bureau, Department of Scientific and Industrial Research, for carrying out the analyses.

REFERENCES

ATKINSON, J. D., 1944: *Orchardist of N.Z. 17* (11), 8.
TAYLOR, G. G. and BURNS, M. M., 1948: *N.Z. J. Sci. Tech. 20*: 115A-119A.

CONTROL OF DOCKS

By A. J. Healy, Botany Division, Department of Scientific and Industrial Research

(*Received for publication, 10 June 1952*)

The introduced docks (*Rumex* spp.) are widely distributed, persistent and troublesome weeds in New Zealand, occurring generally in damp waste places, arable land, gardens, orchards and pastures. A number of species have been accidentally introduced, of which the broad-leaved dock (*Rumex obtusifolius* Linn.) and the curled-leaved dock (R. *crispus* Linn.) have proved of greatest importance.

Docks are propagated sexually by means of 1-seeded achenes, which are produced in profusion, and vegetatively by shoots from the stout root; this latter method is facilitated by division of the roots during mechanical cultivation.

Control measures—manual, mechanical and chemical—have been employed in the past, with varying degrees of success; the recent advent of the hormone-type weedicide has offered some measure of solution of the control problem.

Fig. 1.—Dock (*Rumex*) roots, showing production of shoots from the upper portions only. Photograph: E. Thornley, D.S.I.R. (Scale in centimetres).

Lynch (1947-1948) has indicated that several species of *Rumex* are susceptible to hormone sprays under New Zealand conditions, but that complete control is not likely with a single application.

There are, however, certain circumstances under which hormone-type weedicides cannot be used with safety, and a search was made through weed control literature for a means of control less laborious than the manual excavation of the whole root system.

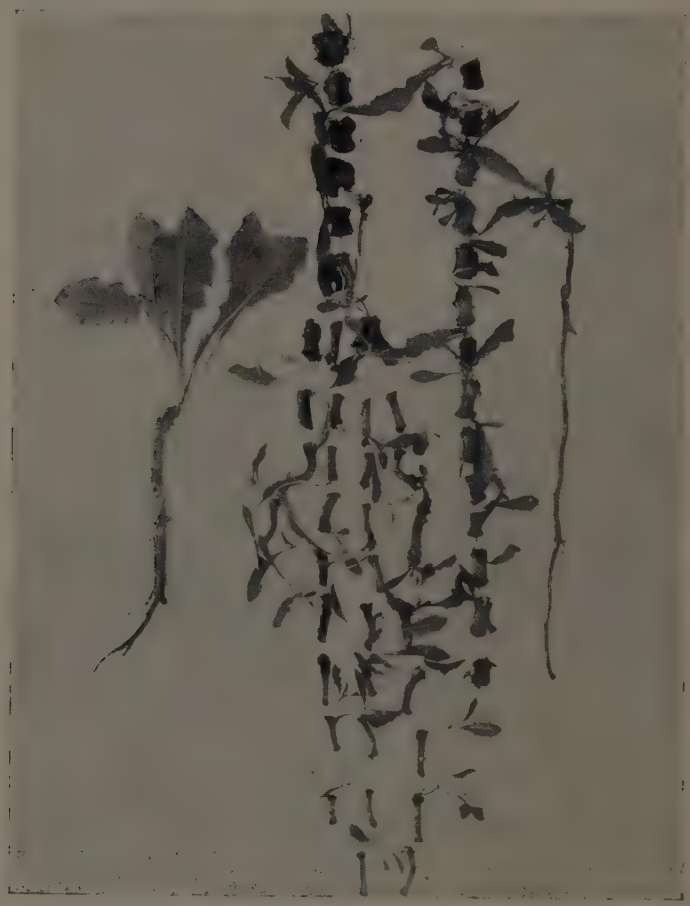

FIG. 2.—Dandelion (*Taraxacum*) roots, showing production of shoots from all portions of the roots, and branching of a root (second from left) due to prior cultivation injury. Photograph: A. L. Bryant, Department of Agriculture.

An account by an anonymous worker (1950) in an English farming journal dealing with regeneration of dock roots and application of the knowledge to control measures seemed to offer a solution to the problem of control where chemical control was not practicable; it was stated that, contrary to popular belief, dock roots did not regenerate along their whole length, that in *R. obtusifolius* Linn. new shoots arose only from the upper 2.5-3.0 in. of the root, and that in *R. crispus* Linn. new shoots arose from the upper 1.0-1.5 in. of the root.

The conclusions of this English worker were verified by a series of experiments carried out with New Zealand material. Roots of the two common species were cut into segments one-half inch long, and the segments planted in soil; root material from plants at pre-flowering, flowering, seeding and post-seeding stages of development were used in the experiments, which were carried out during the period 1950-52. One of the experiments is shown in Fig. 1, the root on the left showing regeneration to a depth of approximately 2.5 in.

From the results secured in these experiments, it is suggested that if dock roots are cut with a grubber, sharpened docking iron or a similar implement, below three inches from the crown, there is no danger of subsequent regeneration from the basal portions of the root left in the ground after the crown portion is removed (and disposed of). The necessity for forking or digging-out the complete root is obviated.

The results obtained offer an explanation why shallow spudding gives no measure of control, leaving as it does a part of the regenerative section of the root intact in the soil; they also show the incorrectness of the oft-held belief that all portions of a dock root are capable of giving rise to new plants.

By way of contrast in behaviour of roots, Fig. 2 shows roots of the common dandelion (*Taraxacum officinale* Weber.) used for a similar experiment. All portions of the root demonstrate ability to produce new shoots, and indicate the reason for failure to secure any measure of control of this weed by either shallow or deep spudding.

The writer wishes to express his thanks for the photographs to Mr. E. J. Thornley, Department of Scientific and Industrial Research, Wellington, and Mr. A. L. Bryant, Animal Research Station, Department of Agriculture, Wallaceville.

REFERENCES

ANON (1950): Agricultural Progress. The Control of Docks. *Farming*, *4*: 97-8.

LYNCH, P. B. (1947): Results of Trials with Hormone Weedkillers. *N.Z. J. Agric. 75*: 119, 127.

———— (1948): Chemical methods of Weed Control. *N.Z. J. Agric.*, *77*: 442.

BOOK REVIEW

THE GRASS CROP: ITS DEVELOPMENT, USE AND MAINTENANCE

by WILLIAM DAVIES, D.Sc. E. & F. N. Spon Ltd., London. 274 pp. 35/-.

This book is the latest addition to the well-known agricultural series edited by Prof. H. G. Saunders. In it Dr. Davies gives an historical and geographical review of grassland developments and covers in some detail the experimental and field survey work relating to requirements for better pastures in Britain.

There is probably no one with a better background of training and experience for this task than Dr. Davies, who has during a lifetime of grassland research, travelled and worked in most of the world's important grassland areas. The influence of this background is clearly seen in many parts of the book, and the author draws directly from his personal experience to illustrate many important ecological and geographic points.

Dr. Davies' approach to pasture productivity is the ecological one, and he lays particular emphasis on the pasture association as one of a series of successional phases or seres. For example, the normal vegetation succession in the climatic conditions of North Western Europe and of New Zealand is to climax associations of woodland or forests; it is the aim of the grassland farmer to prevent the complete succession, and to hold the seral development at the best pasture stage.

A considerable part of the book is devoted to the practices necessary to achieve this end under the very diverse environmental conditions under which pastures are grown throughout the world. The ecological approach is most important at the extremes of the edaphic scale; under dry conditions overgrazing causes rapid deterioration of the sward, and subsequent regeneration is a long and difficult task. Similarly under wet conditions, the natural tendency to scrub and forest calls for special attention to avoid weakening the pasture and allowing the reversion to start.

The author considers the individual factors involved not only in maintaining grassland but also in deriving from it the maximum amount of herbage. The importance of better strains, the effect of clovers and animal manure in the nitrogen economy of the pasture, the place of fertilisers, and the importance of good grazing management are all dealt with in detail. By fitting all these together Dr. Davies develops an excellent case for ley farming in Britain. He views the ley as a special crop which is of value not only for its own herbage production but also for its beneficial effects on soil structure and fertility, and thus on the yields of subsequent forage or grain crops. Seeds mixtures for British conditions, together with information on appropriate management practices, are given in some detail.

The final chapter on grassland research is a useful summary, and it is a little surprising to find it relegated to the position of a postscript in small type. New Zealand pasture research workers will however feel quite smug that Dr. Davies' suggestion of wide crosses among ryegrass species, is an accomplished fact in this country, even to the extent that a considerable amount of seed from such hybrids is being commercially exported to Britain.

It is, however, only natural that a reviewer of this book with its very wide coverage, should be able to find a few points with which to disagree. For example the statement (p. 177) that a favourable climate is perhaps the least of the reasons why New Zealand does not have to house stock at any period of the year, will puzzle many readers, as it does your reviewer, especially as Dr. Davies does not give what, in his opinion, are the main reasons.

On a more general basis it is somewhat surprising that Dr. Davies has not given more space to the soil and climatic variability within Great Britain, and to any adjustments required in species, seedings and grazing practice to meet local conditions. A considerable amount of such local adjustment is certainly necessary within New Zealand, especially from West to East, and it would have been interesting to have Dr. Davies' opinions of regional differences within Britain.

Perhaps the weakest feature of the book lies in the lack of references in the text to the extensive bibliography presented. In only a few cases is it possible to find what authorities are quoted for any particular section. In view of the author's statement that the book is intended primarily for the farmer it would probably have been better to delete this bibliography in favour of further illustrations.

P.D.S.

BOOK REVIEW

PHOTOSENSITIZATION IN DISEASES OF DOMESTIC ANIMALS

By N. T. Clare, Review Series No. 3 of the Commonwealth Bureau of Animal Health. Published by Commonwealth Agricultural Bureaux, Farnham Royal, Bucks, England, 1952. Price, 7s. 6d.

The author of this publication is an active worker in the field under review, and some of its merits are clearly attributable to this fact.

The review opens with a note on the meaning of the words "photosensitivity" and "photosensitization". One can agree that the arbitrary definitions are not entirely satisfactory, but the hope that they will be an aid to clarity is hardly realised. For instance, the review covers much more than "the syndrome which develops when an animal which is in a state of photosensitiviey is exposed to sunlight," which is the definition given to "photosensitization," the word used in the title.

The chemistry and physiology of photosensitivity are discussed under the following headings: Historical; The Nature and Mechanism of Photodynamic Action; Distinction between Sunburn and Photosensitization (or should it be photosensitivity); Experimental Establishment of the Aetiology of Photosensitivity; The Syndrome of Photosensitization. These sections give an excellent condensed account of present beliefs concerning the mechanism of photosensitivity.

The various photosensitivity diseases are then discussed in four classes: Primary Photosensitivity; Photosensitivity due to Aberrant Pigment Synthesis; Hepatogenous Photosensitivity; Photosensitivity of uncertain Aetiology.

The review closes with a very thoughtful discussion of the investigation of photosensitivity diseases.

144 references are listed, and the appendix names 55 plants known to produce or suspected of producing photosensitivity.

It is pleasing that a New Zealand worker should have been chosen to write this review, and the pleasure is accentuated by the efficiency with which the author has completed his assignment.

J.F.F.

COMMONWEALTH AGRICULTURAL BUREAUX

List of publications issued between May and December, 1952.

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Entomology	1. The Injurious insects of the British Commonwealth.
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	2. Subject Index to Animal Breeding Abstracts, Vols. 8/15 (1940-47).
Animal Health	1. Photosensitization in diseases of Domestic Animals.
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